⑦

Draft report
for comments only

ECONOMIC ANALYSIS OF PRODUCTIVITY AND EQUITY ISSUES IN IRRIGATION DISTRIBUTION

U.S.A.I.D. - Government of Sri Lanka
Water Management Project
(Gal Oya)

C.M. Wijayaratna
Agrarian Research and Training Institute
March 1984

TABLE OF CONTENTS

APPENDIX page

LIST OF TABLES

LIST OF FIGURES

Chapter I

INTRODUCTION AND METHODOLOGY

I.I. GENERAL

For more than half a century, the government sponsored colonization programme to played a vital role in the social and economic life of the people of Sri Lanka. However, with the increased pressure on cultivable land, enhance cost in the development and mainrenance of water resources possibly combined with new technologies in agriculture which depend upon assured supply and its judicious use, improved water management in the existing schemes has now become a key element in the irrigation policy. As such, in order to analyze the factors affecting the better utilization of irrigation water, it becomes necessary to learn how the systems operate at present. An intensive study of socio-economic, agronomic and engineering aspects of water management, with special emphasis on identifying the constraints on farmers' decision making process, would thus become imperative. The Agrarian Research and Training Institute (ARTI) with the assistance of Rural Development Committee of Cornell University, U.S.A, has undertaken such a task, and this report is an outcome of this programme (I).

This is essentially an analysis of the spatial distribution of irrigation water, yield and income in the Gal Oya (Left Bank, L.B.) settlement scheme of SRi Lanka. The study was conducted with financial assistance from United States Agency for International Development (U.S.A.I.D.) and the Irrigation Department (I.D.) of Sri Lanka.

The report is organized into four chapters. In the remaining part of this chapter we will provide some backgournd information on the study area and elaborate on the scope of the study and the methodologies adopted in data gathering. Since an important objective of the overall research programme is to analyze appropriate farm-level data in order to understand the constraints to and potential for increasing productivity in large irrigation schemes of Sri Lanka, in the second chapter of this report an attempt is being made to develop a methodology to study water availability at the farm level and subsequently the spatial distribution of irrigation water in the Gal Oya Left Bank (will be analysed). The relationships between a) the source of irrigation, water adequacy at farm level and b) some other selected aspects in farming such as tenurial conditions and input use will be examined in the third chapter. Yield levels of different locations of Gal Oya Left Bank System are presented in the final chapter together with an analysis of the influence of water and fertilizer on yield levels of a selected hydrological unit. unit. In addition, the input use and profitability of paddy farming at various locations is also presented in the form of crop budgets. As far as possible dry season versus wet season comparison is attempted throughout the analysis.

I.2 GAL OYA SETTLEMENT SCHEME

Gal Oya settlement scheme is one of the largest irrigation projects in Sri Lanka and covers a geographical area of about I550sq. Km. It is located in the eastern dry zone of the country, mainly in the Ampara district with part lying in the southern part of Batticaloa district. Population details are given in Table I.I. below. The main reservoir, formed by earthern dam across Gal Oya river, at a narrow gap in the valley by the Inginiyagola hills, has a storage capacity of nearly 950 million cubic meters (770,000 acre feet) at full supply. The scheme was designed to provide irrigation for 48,600 ha (=20,000 acres) with the Left BAnk channels serving nearly half this amount (see Figures I.I and I.2 for project location and water flow).

The catchment area (which covers over about I,800 sq. Km) receives an average of about 2,000 mm (83 inches) of annual rainfall. However, the rainfall is spread over about I00 days in the year, of which nearly 7[illegible] percent comes during the northeast monsoon period, usually October to February. A 'lowland paddy crop' during the Yala season is possible only on irrigated lands, while in the main season (Maha) supplementary irrigation is necessary to incure a successful paddy crop.[I]

I.2.I. Left Bank Development

The reservoir and main distribution system for the Gal Oya Left Bank (LB) were completed in I952. Settlement of colonists bagan at about the same time. Nearly forty colonization units encompassing approximately 6000 households were settled on the L.B. command area at the inception of the project. The size of each allotment was about I.2 - I.4 ha (3-4 acres) of paddy land and about 0.4 ha of highland for a house, garden and subsidiary food crops. Interspersed with these units in the L.B. area are private lands with or without water rights.[2]

Table I.I.

Distribution of Major Ethnic Groups Among Left Bank, River Division, and Right Bank, Gal Oya System, I98I*

Subsystem		Sinhalese	Tamil	Moor	Other	Total
Left Bank	No:	64,45I	42,II4	I8,200	327	I25,092
		(5I.5)	(33.7)	(I4.5)	(0.3)	(I00)
River Div.	no:	3,228	4I,085	II0,II9	690	I55,I22
	%	(2,I)	(26.5)	(7I.0)	(0.4)	(I00)
Right Bank	no:	I2,084	5,975	I9,436	99	37,594
	%	(32.I)	(I5.9)	(5I.7)	(0.3)	(I00)
Total	no:	79,763	89,I73	I47,755	I,II7	[illegible]
	%	(25.I)	(28.I)	(46.5)	(0.3)	(I00)

* Source : I98I Census.

---

[1]
Paddy = Unhusked rice
Yala = 'dry season' (April - August)
Maha = 'wet season' (October-March)

[2] Holdings pre-existing the scheme's establishment are mostly with water rights, whereas 'encroachments' (unauthorised cultivations) do not have water rights. OUr discussion will return to this point later.

As the colonization programme, continued, increasing amounts of land were brought under cultivation. By I965 a nominal area of about I8,000 ha(44,500 acres) was under irrigation in the L.B. command area. In addition, the development of sugar can plantations on the Right Bank (R.B.) with a priority water right placed increasing demand on reservoir storage. Interviews with original colonists, conducted by the Agrarian Research and Training Institute (ARTI) in March I980, indicated that in early years water deliveries were continuous throughout both seasons and ample down to the lower boundary of the L.B. command area (I6). However, many of these respondents date the cessation of continuous water deliveries to L.B. paddy to the R.B. development in the early sixties. More than that, with the increased population pressure, encroachments on drainage and right-of-way reservations and right-of-way reservations and the aswaddumization [3] of land earmarked for upland crops has continued

Figure 1.1: Map of Project Area

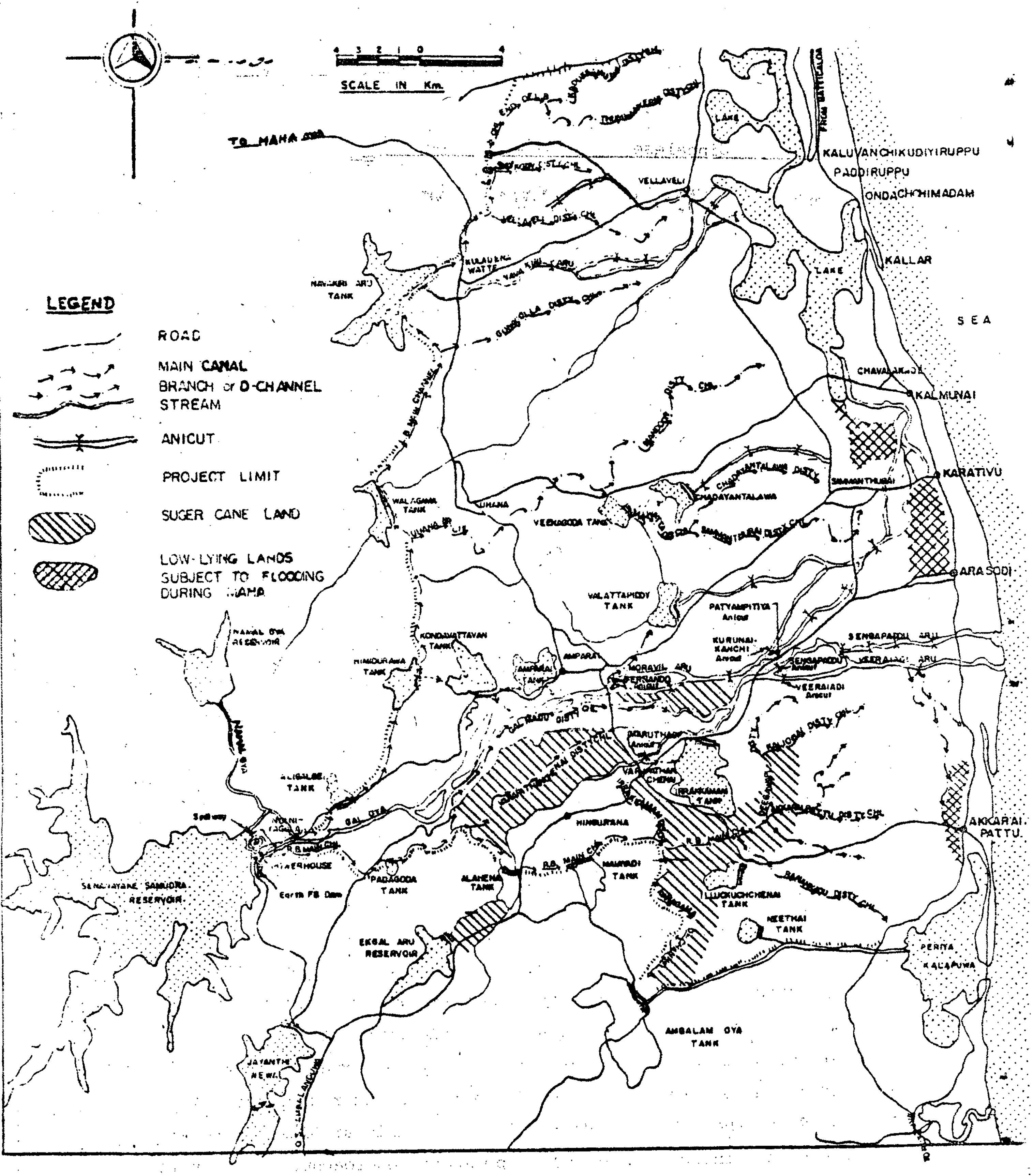
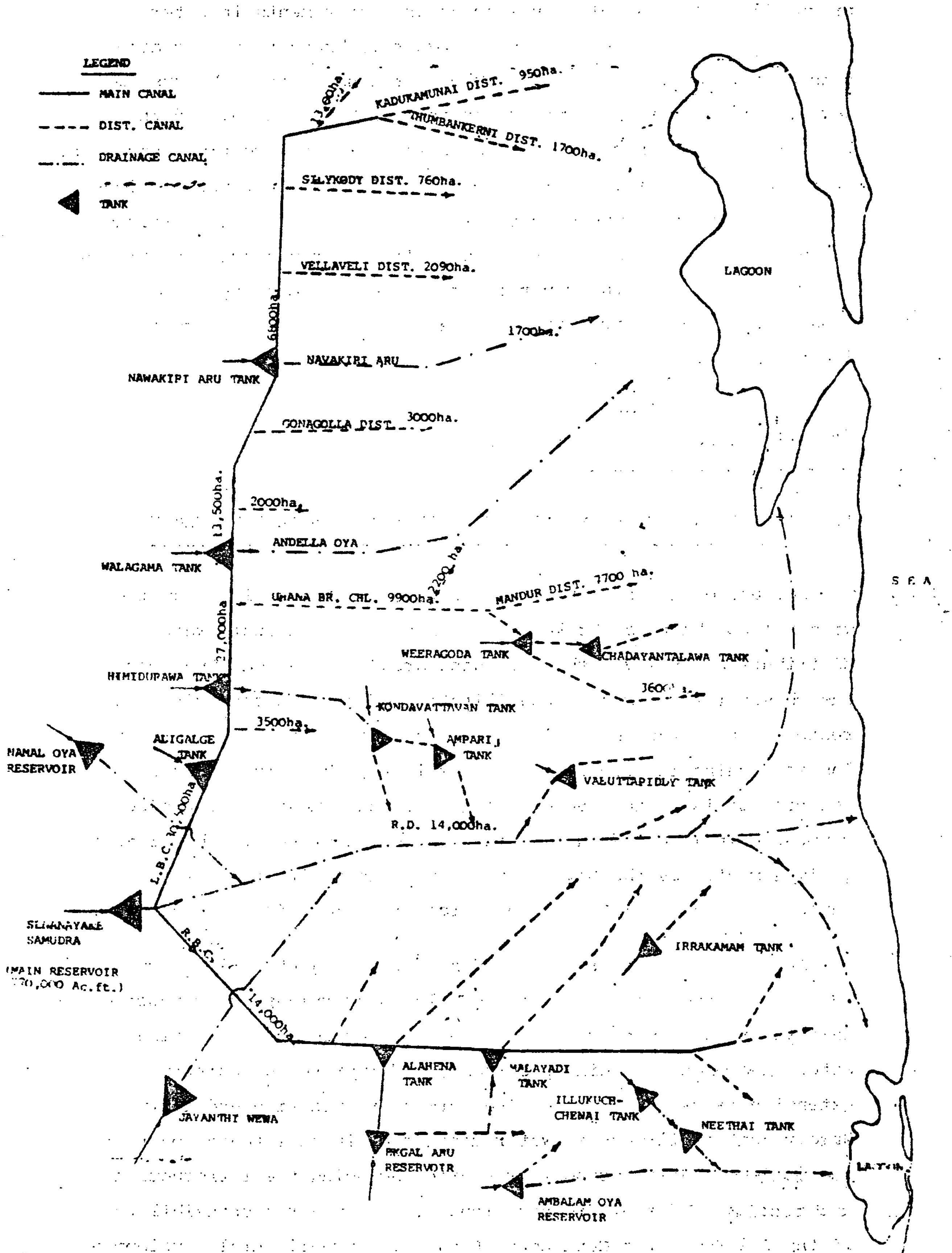


Figure 1.2: Gal Oya Project – Line Schematic



NOTE:- EXTENTS GIVEN ARE ESTIMATED FIGURES OF PADDY LANDS PRESENTLY CULTIVATED.

IRRIGATION DEPARTMENT
JANUARY 19[illegible]

to increase the area under paddy. Currently it is estimated that paddy is being grown as much as 24,000 ha (60,000 acres) of L.B. land during a normal Maha season. Land efficient techniques of production, water supply development or improvements in water management efficiencies were not adequately brought in, and as a consequence, by the end of the 1970s portions of the L.B. system have reverted to rainfed status during the Maha season, and the L.B. area which can be cultivated during Yala was greatly restricted. At the same time drainage problems were observed in upper portions of certain channels where over irrigation occurs, and in portions of the tailend of some channels where losses from above accumulates. In addition many of the control gates have been destroyed. As a consequence, the control of water was possible only at very few locations (9,I2,I6,I7).

I.3 THE WATER MANAGEMENT PROJECT = ARTI / CORNELL INVOLVEMENT

Because of the serious deterioration of the physical system with silted channels, broken structures, and inadequate water distribution, in I978, the Left Bank area[4] of the Gal Oya Scheme, was chosen for a major rehabilitation effort. Recognizing that restoration of the physical system alone would not make for any lasting gains in productivity and welfare, the main purpose of the project is to improve overall water management. The project commenced in late I979 and is in progress at present. The project is implemented by the Government of Sri Lanka with financial assistance from USAID. I.D. is responsible for project implementation,

According to the project proposal, the project will modernize the L.B. of the Gal Oya scheme, develop masterpland and conduct on farm water management research, create an improved irrigation water management training programme, and improve the existing extension programme. Promoting farmer organization and active involvement of farmers in water management is an integral part of the project. Socio-economic research including the introduction and testing of farmer organizations, is the major responsibility of the Gal Oya Water Management Project. Cornell Rural Development Committee provides consulting services to ARTI, in this connection.

---

[3] To bring land under cultivation.

The ARTI has conducted a baseline survey of the project in March 1980 and a detailed farm record keeping programme which was launched in 1979/80 wet season and continued since then, is in progress at present.

---

[4] The L.B. system is estimated to consist of nearly 52 Km of main channels, 145 Km of major distributaries, about 445 Km of minor distributaries, and approximately 685 Km of field channels.

I.4 SCOPE OF THE PRESENT STUDY

As the socio-economic survey conducted at the beginning of the research programme had indicated, the poor results of the Gal Oya water management plans may be mostly a consequence of the lack of farmers acceptance. The plans developed at the administrative level and applied at the farm level were most susceptible to failure at the implementation stage. Lack of integrated approach to water management; in other words the lack of integration of the socio-economic aspects with agronomic and engineering aspects was seen to be the weak link in this process. Thus a management approach which a) considers the socio-economic and technical aspects at farm level and b) invloves farmers during the process might have the potential of success. To facilitate this approach a series of research studies were planned and the present one is one of them, comes under the Special Study Series of ARTI / Cornell Water Management Research Programme.

The objectives and the nature of the present study evolved from the preliminary analysis of the farmers' circumstances and behavior in relation to water use and agricultural production. In broad overall terms, the purpose of the investigation, as stated in the proposal,[5] (entitled Economic Analysis of Some Productivity and Equity Issues in Irrigation Distribution) is to analyse the spatial distribution of a) water, b) yield and c) income in the Gal Oya Left Bank System. In addition the analysis would also help to determine the relative value of irrigation water in alternative distribution models such as a) wet season versus dry season, b) between subsystem distribution, c) 'between distributary channel' distribution and d) 'within distributary channel' distribution etc.

Further, it is hoped that the present analysis would help to modify the management of the main system in order to obtain a better balance between water deliveries and water demands.

The more specific objectives of the proposed analysis would be:[5]

1. Develop simple indicators to assess the reliability and adequacy of water input in Irrigation Scheme which in turn could be used in ;

   a) The analysis of productivity and equity aspects of water distribution and

   b) Monitoring the performance of Irrigation Management.

2. Study the crop response to water status.

3. Compare main and terminal systems in terms of water status, yields and income. The analysis will be carried out for:

   a) differenct subsystems
   b) branch channel command areas
   c) field channel command areas and
   d) channel bifurcation and distance factors faced by the individual farms.

   In addition the analysis will be extended to a dry season versus wet season comparison.

4. Analyse the resource use characteristics, including the use of ' improved technology' in paddy farming in the Gal Oya Left Bank System. This analysis will be used to compare different tenurial conditions, namely :

   a) Colony holdings versus encroachments and private lands

   b) Owner operators versus tenant cultivators, etc.

---

[5] Quoted from the original research proposal of this study, approved by the ARTI, I.D. and USAID , namely A Proposal for a Special Research Study on Water Management Under USAID/GSL Water Management Project (Gal Oya): Economic analysis of some productivity and equity issues in irrigation distribution.

I.5 DATA BASE

The implementation of the objectives described in the previous section call for statistical estimates of the relations mentioned and there fore requires data that incorporate the diversity of the Gal Oya Left Bank System in respect to water availability and other relevent aspects such as socio-economic and agronomic factors. Cross-sectional farm survey data, if collected from a properly designed sample, and if continued for a number of crop seasons, may provide considerable variability in crop yields and input use across farms and also numerous other details. In such data, the quantitative, qualitative, and management levels are determined by the farmers and , therefore, reflect various physical and economic constraints that the farmers face. From such data better specifications may be possible estimating crop response functions, demand functions, and other functions. The results obtained from such estimated should be more relevant to the various policies and programmes designed to help increase agricultural production and general welfare of the settlers. For generating such data, a fairly large-scale yet intensive farm record keeping programme was planned and this was commenced in the I979/80 Maha season. The organization of this survey and the selection of samples are discussed in the next section.

I.5.I. Design of the Farm Survey

The organization and development of the overall design of the farm survey for the entire research programme involved a simultaneous consideration of I) selection of the field locations, 2) selection of smaple farms, 3) designing the farm record book, 4) selection and training of field staff, 5) implementation of the record-keeping programme, 6) transferring and coding of data gathered and 7) bedgeting.

I.5.2 Selection of the smaple

Despite the fact that present analysis is confined to the data gathered during the I98I/ 82 Maha and I982 Yala crop seasons we will describe briefly the sampling procedures adopted since the inception of the record keeping programme : i.e. from the I979/80 Maha season. This is attempted here because we had to modify the sampling method three times since the I979 Maha season and these details are not properly documented elsewhere.

(a) I979/80 Maha and I98I Yala seasons : The sampling technique adopted for the rd keeping programme for the I979/80 Maha season was a two-stage stratified, random sample design with 'colony units' as the primary sampling units, field field channels as the secondary units, and allotments along selected field channels as the tertiary sampling units.[6] Nearly 50 percent of the 'colony units' in the Left Bank area were selected randomly at the first stage. At the second stage of sampling along a major distributary channel (D-channel) within the colony unit area, three field channels were selected to represent the head, middle and tail portions of the distributary's command area.

Maps of the Gal Oya Schemes and the list of all the colony units were used in the selection of colony units, and the field channels. Detailed 'block-out-plans' of the colony units were used at the next stage to select the ultimate units of the record-keeping programes, namely the farm blocks. This was an exception to the conventional approach adapted in similar farm surveys that time. In almost all of our earlier socio-economic surveys (in the paddy sector) we had selected farmers from the paddy land register (or lists of households available from some other source) of the villages selected. Obviously this method is not appropriate to a study focused on water management. Therefore our selection (of farms) were based on the lower level hydrological units, namely the field channels.[7] If the number of allotments on a selected field channel was less than 20, all were included in the study; if there were more than 20, a random sample of 20 was taken. The total number of allotments selected from the respective command areas of these field channels was 368. The total number of farmers operating on the sample of allotments selected in the sample area, on the average, was 60 percent higher than the number of allotments. It was evident that this was due to changes that had occurred in the tenurial pattern since the inception of the programme, such as : dividing the original allotment among the children of an original settler, and other illegal land transactions leading to fragmentation of holdings. Therefore, the total number of farms / farmers included in the final sample for the record keeping programme of the Left Bank of Gal Oya in the I979/80 Maha season was 536.

---

[6] Random digit-tables were used for randomization of all stages.

---

[7] It should be noted that the limitations of the 'paddy lands register approach' is well known: for instance, more often than not it is not a complete list of farmers as it does not include tenant cultivators,etc.

In addition, three additional sites outside the rehabilitation project area were selected for comparison purposes. Two of these were from the Right Bank of Gal Oya and the other from the River Division. The methodology adopted in the selection of field channels, farms, etc. and the type of information gathered in these three area were similar to those for the Left Bank. The colony units/villages selected and the number of farmers inlcuded in each one of sample sites are given below.

TABLE I.2

List of Colony Units/Villages and the Numbers of Farmers Included in the Sample I979/80 Maha season

I Left Bank

Colony Units	No. of Farmers
2	37
3	39
7	24
8	34
IO	2I
I4	I9
I7	36
2I	49
22-23	53
24	23
26	24
30	54
32	24
35	22
39	20
Block 'J'	22
Block 'E'	I8
Block 'D'	I7
	536

II Right Bank

Village	No. of Farmers
II A	20
23 A	22

III River Division

Village	No. o'
Sengapadai	20

Left Bank	536
Right Bank	42
River Division	20
	598

The changes made in the sample in the next season, i.e.,1980 Yala, were not many. Despite the fact that added advantages are realized (which are mentioned below) of focusing on complete D-channel units we attempted to maintain the same sample (as of previous Maha), as far as possible, to gather information of some farms for a complete crop year. However, bacause of the large sample size and adequate spatial distribution of the sample, it was possible to make meaningful comparisons between zones, subsystems, and D-Channels.[8] Some areas of the Left Bank system were left uncultivated during 1980 Yala due to lack of irrigation and consequently minor changes in the sample were made at the beginning of this season.

1980/81 Maha and 1981 Yala seasons: Major changes in the sampling procedures were done at the beginning of 1980/81 Maha season. Initial analysis of data gathered through the record keeping analysis and the baseline survey[9] had indicated the importance of focusing future research efforts on 'D-channel units' instead of 'colony units.' We assumed that such an effort would lead to get more correct measures of hydrological differences within the system. The designation of field channels as 'head' 'middle' or tail along a distributary studied in the previous seasons was fixed within each'colony unit' under study - and since D-channels sometimes cross the colony unit boundaries, a 'head end' field channel within a unit could be middle or tail according to the whole distributary configuration. Alternatively, a field channel designated as'tail' within the colony unit's boundaries could be ahead of field channels along the same distributary, if the latter stretched into another colony unit. Because I) the variability within field channels (in regard to water availability and yield levels) found to be less significant compared to the variability between field channels (of the same distributary) and b) the variability between distributary channels is even much more significant than those mentioned above. Thus we decided to ignore the location of farms within the field channel at the sampling stage.

At this juncture of time, based on hydrological considerations we divided the Gal Oya Left Bank system into nine 'subsystems.'

This was done hypothetically for research purposes.[IO] These subsystems, however, could be broadly classified under four categories, namely:

I. L.B.Main
2. Uhana - Mandur
3. Gonagolla
4. Navakiri

However, our analysis will not be based on the said broad classification as we assume the subsystem-wise classification as more appropriate. Given the locations of subtanks and major regulators, these subsystems may be regarded as more or less independent ' hydrological units' themselves. This classification is illustrated in Figure I.3

---

[8] See, I980 Yearbook for Sri Lanka Water Management Research: Initial Analysis of Pre-rehabilitation situation in Left Bank Gal Oya, for such an analysis.

[9] A supplementary questionnaire survey was carried out in March which covdred all the farms included with record keeping activity and 300 additional households from the River Division (20I) and Right Bank (99) of the Gal Oya Scheme. Details of sampling procedures can be found in I98) Yearbook for Sri Lanka Water Management Research.

[Io] This classification was used by the author in an earlier analysis.

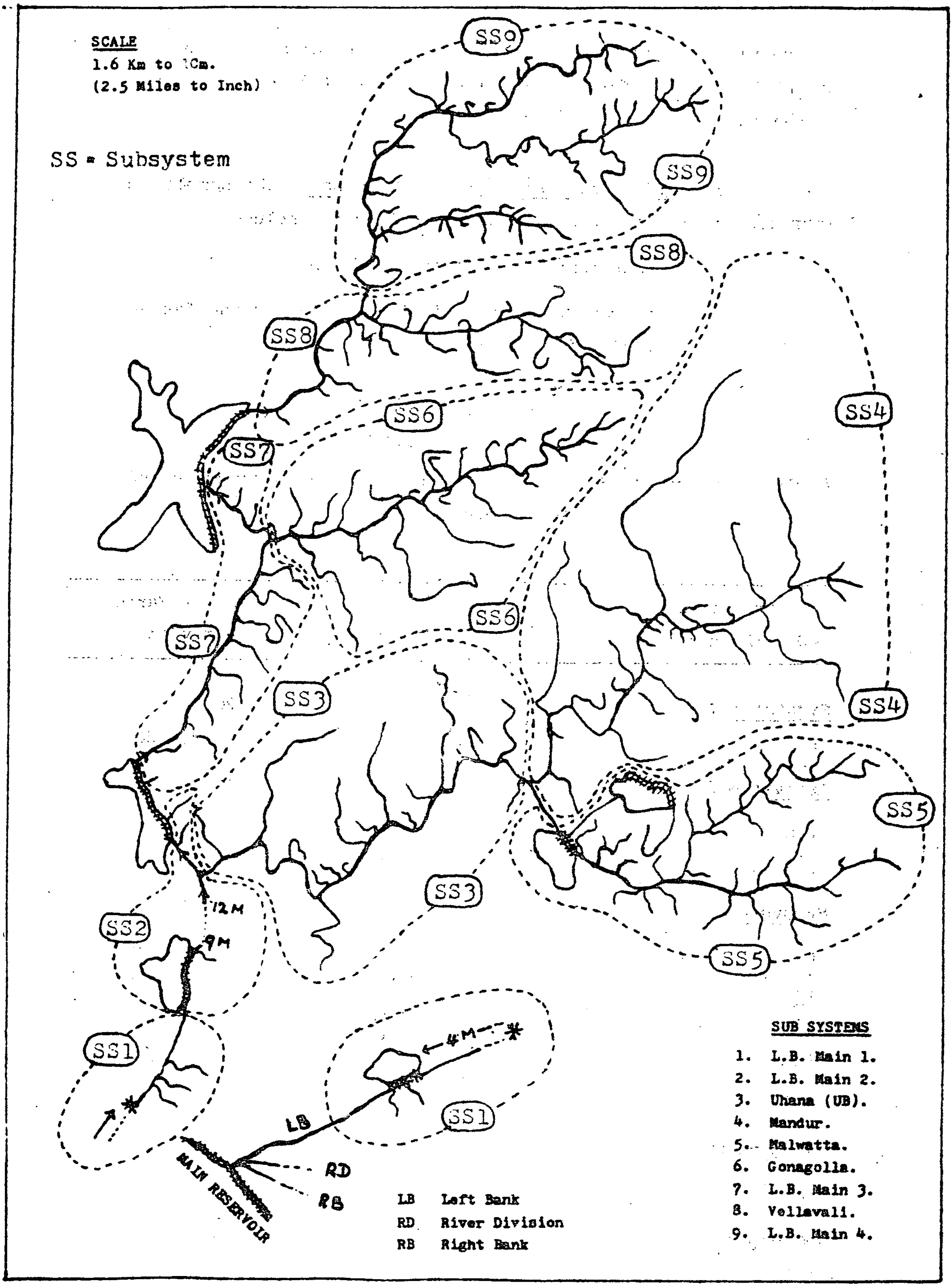
The number of distributaries selected from each one of these subsystems was dependent on the relative extent of the system. Selection of farms were done randomly in a similar manner described earlier. However, we had to cut down the size of the (total) sample considerably due to resource limitations. At this point in time the ARTI was planning to launch a pilot (action-research) project on farmer-organizations and the budgetary negotiations between ARTI and I.D. resulted in a significant cut in the allocations made for the record - keeping exercise. Thus we basically made the following modifications.

I. Number of farmers selected from a given D-channel* was limited to 20. The total number of farms indluded in the survey therefore reduced from 598 to 260. This was reduced to I8I in the I98I Yala due to similar ressons mentioned earlier. In this season subsystem 5 was dropped, as we thought, in the context of resource limitation, it is better to concentrate on L.B. Main and Uhana-Mandur systems. Subsystem 5, however, was not being selected randomly for this elimination. In the light of logistical and similar resource limitations, elimination of a randomly selected areas may not serve the purpose. Therefore we had to drop either the tailend of the main system or the tailend of the Uhana-Mandur system. As the Uhana branch canel 'divides' into two to form Mandur and subsystem 5, it was considered to be logical to drop one of them. Because of the more or less 'uncommon' characteristics of subsystem 5 (such as the presence of Weevagoda and Chadayanthalawa tanks and the huge unit, Block "J", we conveniently dropped it.

---

* Sampling at this level was based on block out plans. At this time better maps were available and also we managed to prepare accurate lists of cultivators in respective locations.

Figure 1.3: Gal Oya Left Bank - "Subsystems" Classification



2. The sample areas in the Right Bank and the River Division were also dropped.

The samples of I9C0/8I Maha and I98I Yala are classified by subsystem and distributary channels in Table I.3 and the sptial distribution is shown in Figure I.4.

c). <u>I98I/82 Maha and I982 Yala Seasons:</u> The sample was increased in the I98I/82 Maha season mainly to include:

I. encroachments and private lands and
2. areas covered by the pilot activity on the farmer participation programme.

TABLE I.3

I980/8I Maha and I98I Yala Samples Classified by subsystems and Distributary channel

Subsystem and D-channel	No. of Farms I980/8I MAHA		No. of Farms I98I YALA	
<u>Subsystem I</u>	20	20	20	
L.B. 6				20
<u>Subsystem 3</u>	40		40	
U.B. 2		20		20
U.B. 9		20		20
<u>Subsystem 4</u>	Ioo		44	
M_{5}		2I		IO
M_{I2}		20		I7
M_{I6}		20		-
M_{I8}		20		I7
M_{3I}		I9		-
<u>Subsystem5</u>	20		-	
Malwatta D.		20,		-
<u>Subsystem 6</u>	40		20	
G_{4}		20		20
G_{24}		09		-
G_{26}		II		-

Subsystem 6	40		20	
G_4		20		20
G_{24}		09		-
G_{26}		II		-
Subsystem 7	20		37	
L.B.29				I7
L.B.36		20		20
Subsystem 8	20		20	
V_{I2}				20
V_{I6}		20		
Subsystem 9	20		-	
L.B, 48		20		-
Total	280		I8I	

A firm decision on the issuance of 'legal rights' to cultivators who have 'encroached' the 'reserved' lands (i.e., unauthorised cultivators) is not yet attained. However, we had realized the importance of an analysis of socio-economic conditions and water use patterns in encroached as well as' private lands,'[II] For instance, we thought that these cultivators would become a potential problem in the system managemnet in general, and for farmer participation programmes, in particular. We had also seen a considerable degree of 're-use' of water by the unauthorized cultivators in drainage areas: organized group activities-such as the development of small anicut schemes were also observed in certain cases.[I2]

However, the selection of sample farms to study the 'encroached and private lands' was seen to be a difficult task. Given the resources available to us it was nearly impossible to perform a perfect randomization procedure leading to the selection of an 'unbiased' and manageable sample from the entire 'population' of encroachers and private (i.e., non - colonists) farmers in the project area. However, we were aware of the locations of a) clusters of such holdings and b) those scattered holdings located within or in the peripheries of regular colony areas already included in the sample.

In addition we thought it is better to include such encroachments and private lands in the study because then we can make a comparison between such farms and surrounding 'colony farms'. Consequently, each field investigator was instructed to compile, as far as possible, a complete list of encroached/private farmers in their respective areas. We may regard this as a good coverage because :

1. field staff were well aware of their own areas and
2. it was not difficult to get information on such lands in the peripheral areas because, more often than not, they exist in 'cluster' forms.

Before the final selection of such farmers the investigators prepared 'maps' indicating the location of farms in the lists they prepared. On the average 20 farms were selected randomly from each list/map of locations.[13] The distribution of samples on the basis of a) subsystems, b) D-channels and c) type of operators, is given in TAble 1.4.]

The spatial distribution of the sample farms included in the record-keeping programme for the crop seasons 1980/81 Maha, 1981 Yala, 1981/82 Maha and 1982 Yala are illustrated in Figures 1.4 to 1.6.

1.5.3. Representation and Consistency of the Smaple FArms over Time

The major objectives of the record keeping exercise were :

1. To provide base-line information, to represent pre-project situations, mainly with respect to water distribution in the L.B. system, the use of water and complementary inputs by the L.B. farmer, and yield distribution of L.B.
2. To serve as a monitoring programme, in respect to variables mentioned above, during project implementation (i.e., during rehabilitation).

In regard to both the scale and the nature (intensity) of the record-keeping programme, it could be regarded as a 'unique experiment' in the context of large irrigation schemes of Sri Lanka. Thus, this itself is a learning process and the research methodology adopted at the outset is not necessarily perfect and may need to be refined (as it did) over time.

TABLE 1.4

1981/82 Maha and 1982 Yala Sample Classified by Subsystem, Distributary Channel and Operator Type

Subsystem and D-Channel	I Colony		II Encroachment and Private		I Colony		II Encroachment and Private	
Subsys. 1	30		15		27		11	
L.B.7		17		13		12		11
L.B.10		13		2		15		--
Subsys. 2	30		15		30		15	
D.R. *		--		8		--		10
L.B.14		15		--		15		--
L.B.19		15		7		15		5
Subsys. 3	33		36		34		7	
D.R. *		3		30		--		--
U.B. 2		15		6		20		6
U.B.17		15				14		1
Subsys. 4	36		19		35		--	
M_1		15		--		15		0
M_{16}		--		--		20		0
M31		21		19		--		--
Subsys. 6	38		19		30		5	
D.R.*		4		17		--		--
G_3		15		--		10		5
G_{16}		--		--		20		--
G_{24}		19		2		--		--
Subsys. 7	35		12		32		--	
D.R.*		3		12		--		--
L.B.29		15		--		15		--
L.B.39		17		--		17		--
Subsys. 8	35		20		35		20	
V_2		15		--		15		--
V_{12}		--		--		20		20
V21		20		20		--		--
Subsys. 9	22		31		33		16	
D.R.*		13		--		13		16
S.8		--		--		20		--
L.B.		9		31		--		--
Total	259		167		256		74	

*D.R. = Drainage or Rainfed

Figure 1.4: Spatial Distribution of 1980/81 Maha and 1981 Yala Season Sample Areas

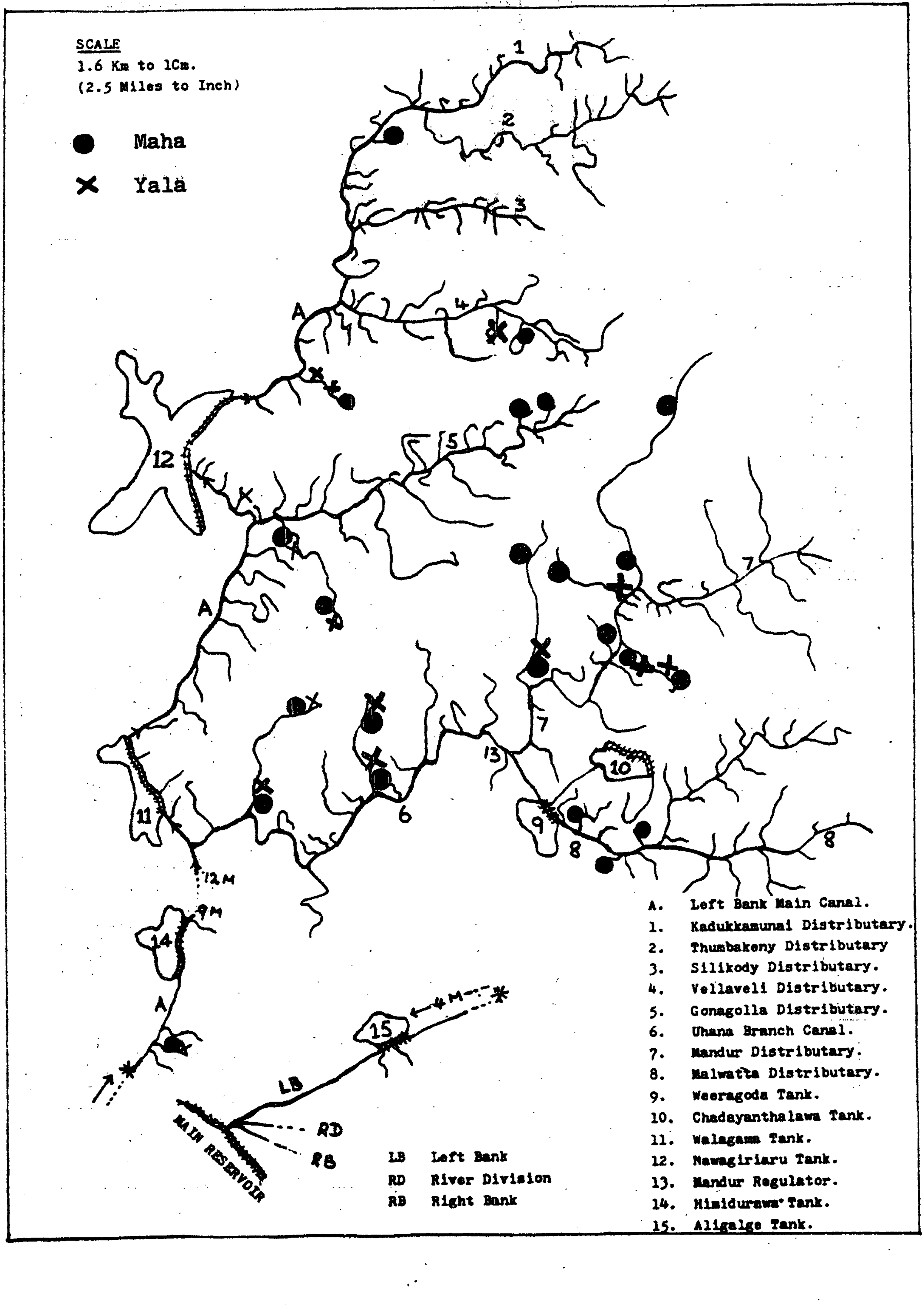


Figure 1.5: Spatial Distribution of 1981/82 Maha Season Sample Areas

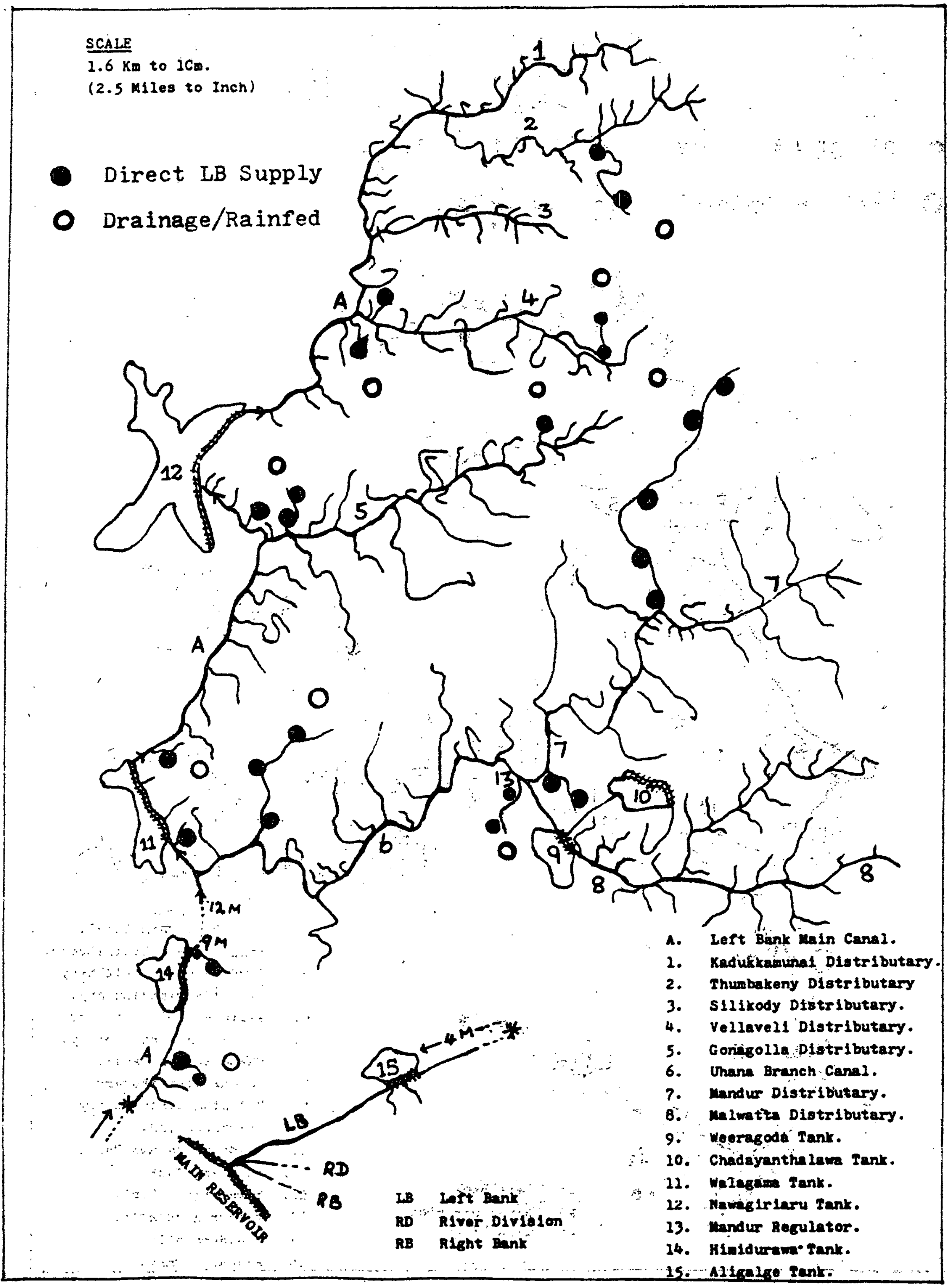
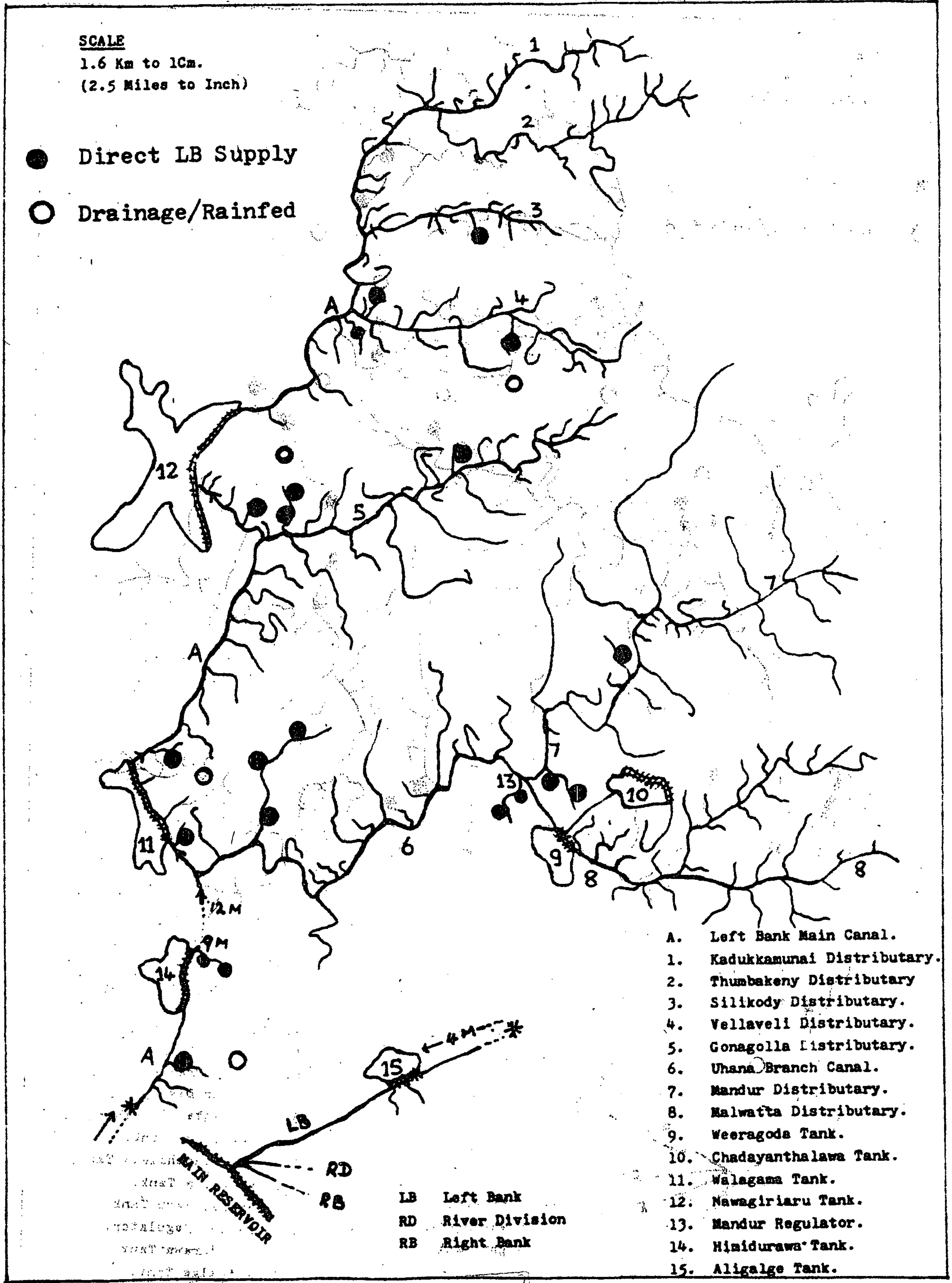


Figure 1.6: Spatial Distribution of 1982 Yala Season Sample Areas



SCALE
1.6 Km to 1Cm.
(2.5 Miles to Inch)

● Direct LB Supply

○ Drainage/Rainfed

LB	Left Bank
RD	River Division
RB	Right Bank

A.	Left Bank Main Canal.
1.	Kadukkamunai Distributary.
2.	Thumbakeny Distributary
3.	Silikody Distributary.
4.	Vellaveli Distributary.
5.	Gonagolla Distributary.
6.	Uhana Branch Canal.
7.	Mandur Distributary.
8.	Malwatta Distributary.
9.	Weeragoda Tank.
10.	Chadayanthalawa Tank.
11.	Walagama Tank.
12.	Nawagiriaru Tank.
13.	Mandur Regulator.
14.	Himidurawa Tank.
15.	Aligalge Tank.

---

[11] The nature of these 'private lands' is mentioned lesewhere in this report. None of these 'areas' were included in the scope of work of ARTI/ contractual agreement between ARTI and I.D. made at the beginning of the research project.

[12] For example in colony unit 29 and in some areas in the <u>Andel Oya</u> downstream. It should be mentioned here that at least, two kinds of records are maintained by the Kachcheri, Ampara, namely: a) claims made by encroachers and regularization of such encroachments and b) information generated by periodical encroachment surveys. However, both these sources do not serve our purpose mainly due to a) inadequacy and incompleteness and b) difficulties in identification.

[13] It should be noted that the encroachments and private lands are not evenly distributed. One may observe clusters of such lands. The location of such clusters depend mostly on the location of drainage channels.

In addition, the resources available to the ARTI and the unusual complexity of the irrigation scheme too, acted as constraints in the process. To quote an example, we still lack precise information on the total cultivable area. Neither do we know if all the encroachers would enjoy legal water rights after rehabilitation. In addition, detailed project maps became available only after the design surveys conducted prior to rehabilitation.

In addition, at the inception of the programme our hypothesis was that variability (in regard to water availability and consequent yield levels) in significant at the field-channel level. As we realised this is not, true[14] and thus we changed our sampling procedure. Then, assuming the importance of encroachments and private lands we changed the sample again (for the second time). Apart from all above as a response to budgetary limitations which were not consistent over time, size of the total sample was adjusted; periodically.

The aggregate result of all these has led to a relative inconsistency of the <u>spatial and size distribution</u> of the record-keeping sample over <u>seasons,</u> despite the fact that we wanted to have a <u>pannel</u> type time-series data. Neverthless, since 1981/82 Maha season, an attempt was being made to maintain a pannel and some of these pannel farmers were included in earlier seasons too. In regard to the D-channel command areas, it could be seen from

---

[14] This implies the importance of main system management.

Tables 1.3 and 1.4 that we have a significant number of D-channels for which farm records are available on a continuous basis, since 1980/81 Maha season.

To monitor the water distribution in the project area, a wider 'spatial' coverage is necessary. This is important to capature the diversity - for instance the multi-dimensional nature of the 'head-tail' problem in water distribution-given the complexity of the channel network (see Figure 1.7). Similarly to improve the representativeness - or in other words to reduce the gap between the true 'parameter' and the estimated 'statistic' in regard to variables such as farm income, farm size, fertilizer use, yield levels, etc., etc., wider spatial coverage of the project area seems to be logical, to capature the diversity.

However, as we see later in Chapter 4 of this report, the more important causal factors for such events as the 'yield variability among farms,' one should closely observe and try to learn the reasons for the differences in farmer behaviour. Such an indepth search was not expected from the record-keeping programme; though it was intensive enough to gather a more or less complete [illegible] input -output data.[15]

It should be noted here that a significant portion of farms, in areas where severe water m shortage is experienced, is left uncultivated during Yala season. If we experienced this situation in sample areas, the procedure adopted was a) Randomly selected another channel from the cultivated are of the same distributary or b) if (a) was not possible then that sample area was left out for the particular season. Therefore, the wet season versus dry season comparison as presented in this report is confined to cultivated Maha and cultivated Yala and therefore does not show a true picture of the constraints faced by those farmers in 'dry areas'. This report is not aimed at the "assessment of the impact of rehabilitation" and suitable adjustments, which of course are possible, should such an effort be made.

---

[15] An indepth study combining a) 'time series' data from the record -keeping exercise and b) detailed survey on causal factors is suggested by Pfof. BArker and is being planned at present. This will be based on a panel of farms confined to one or two selected locations.

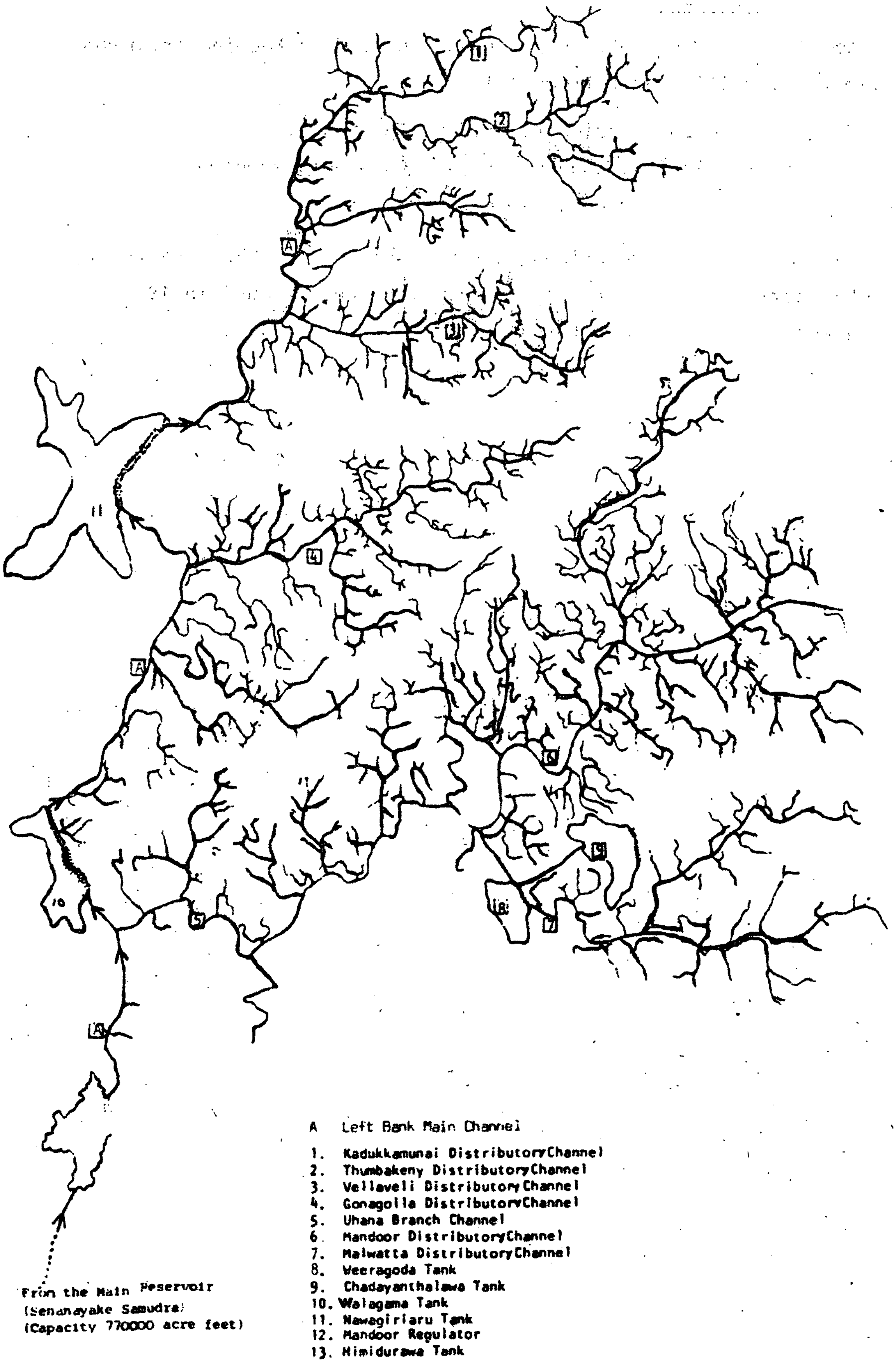
1.5.4. Data Sought

The type of data collected through the record-keeping programme can be classified as follows (16) :

1. Specific information related to water use.
2. Information related to farm and household economy.
3. Social and community aspects.

The record book was comprised of seven schedules. The details of information sought under A,B, and C above can be found in 1980 Yearbook for Sri Lanka Water Management Research (16).

Figure 1.8: Complexity of Channel Network



Chapter II

ADEQUACY AND RELIABILITY OF WATER SUPPLY

The purpose of this chapter is to generate and provide descriptive summary statistics in regard to spatial distribution of water in the Left Bank Command area. This will be based on farm-level (daily) observations on water status in selected farms during 1981/82 Maha and 1982 Yala seasons. will first submit an account on the retionale for using a simple index based on daily observations of water stress and then develop and use an index to describe spatial distribution of irrigation water.

2.1. CROP WATER REQUIREMENTS

Water is critical to the rice plant with respect to four important functions : a) it promotes cell protoplasm growth; b) it is a component of the chemical reaction of photosynthesis; c) it serves as a solvent mechanism for organic and inorganic solutes and gases; and d) it provides plant turgidity (6). In addition,water availability is related to the nutrient status of the soil and the nature and extent of weed growth. Water management therefore affect the physical and physiological aspects of the rice crop, and consequently, its yield.

The lowland paddy rice plant requires water at a rate that is very close to the level of potential evapotranspiration (ET), or the combined rates of evaporation from the soil surface and transpiration from leaf surfaces.

Water requirements of paddy rice for evapotranspiration are about 400-700 mm, depending on climate and length of the total growing period. For instance, in most of the tropics, the evapotranspiration requirements during the rainy season, for a 100 day crop duration, is approximately 400-500 mm. During the dry season the corresponding figure would be 500-700 mm. Evaporation losses tend to become somewhat smaller at shallow submersion or when the top soil partially dries out.

Evapotranspiration increases with vegetative growth and is highest just before flowering to early yield formation, after which is declines somewhat. However, the water requirement of an irrigation system can be substantially higher than the crop water requirement mainly due to a) conveyance and distribution losses, and b) percolation and seepage losses. Percolation losses are a function of the local soil and topographic conditions. Where the soil is heavy, or where the water table is close to the soil surface, percolation losses are low. In some parts of the Gal Oya Left Bank area; the soils are lightly textured, so percolation lossss are observed to be very high. Accurate data on seepage and percolation rates for different locations or a system of planned re-use of return flow are both absent in the Gal Oya scheme. Nevertheless, a significant number of 'unauthorized cultivators' do depend on drainage flow in natural and artificial drainage channels.

A wide range of water use efficiencies can be seen among different irrigation schemes. In Southeast Asia, the system's water requirement varies from about 2500 mm per season (Philippines) to about 650 mm per season (7).

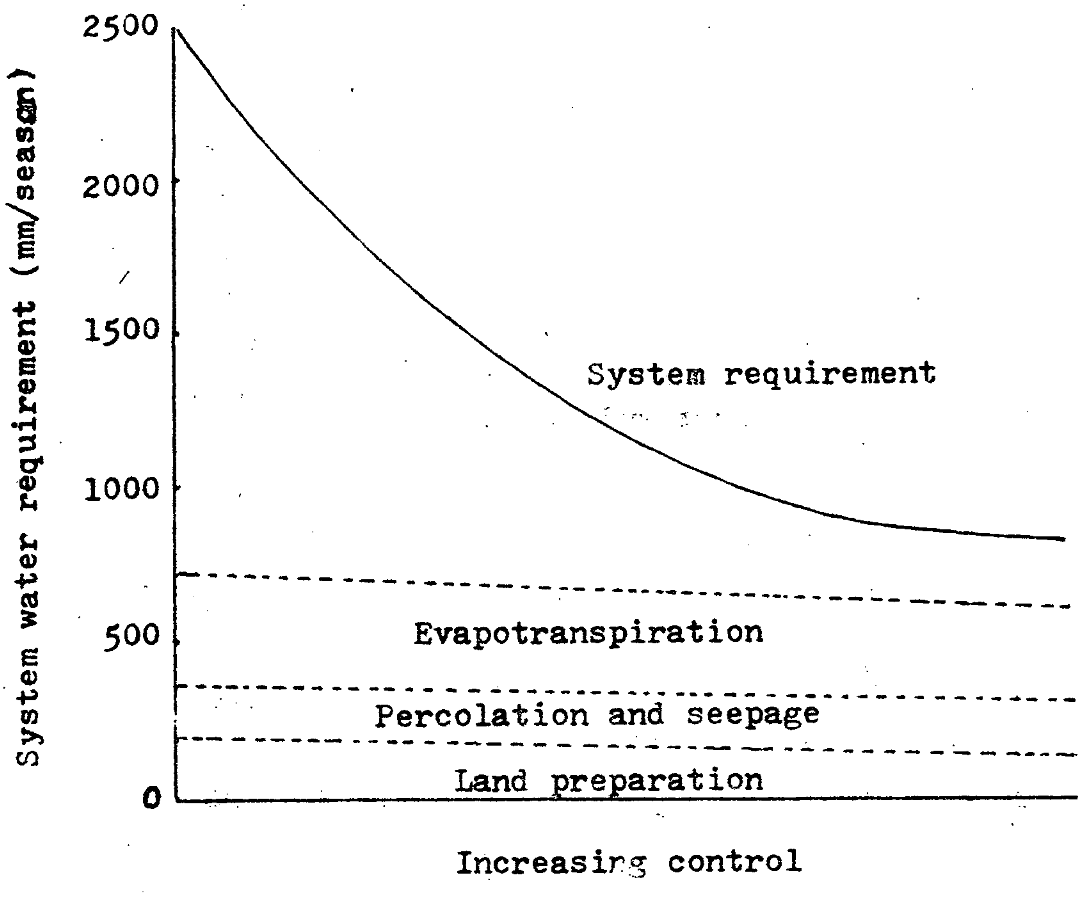
Some systems managed to increase their water use efficiency mainly through improved management techniques. Increased control over water losses through the intensification of physical apparatus (example, extending channel lining to lower levels of the system) has also contributed to improved water use efficiency in some of these systems. In the system considered by this report, water requirement (before rehabilitation) is in the range of 2000-2700.[1] On the other hand, inadequacy and uneven distribution of water has become a common phenomenon in some parts of the system.[2] In the light of these issues, the discussion will now turn towards a strategy to assess water adequacy at farm level in various locations of the system.

---

[1] This is a rough estimate based on I.D. records for cultivated acreage and main system water issues. An interesting account on system operation can be found in (9).

[2] A discussion of possible causal factors can be found in (18).

Figure 2.1: The Irrigation Water Requirement for Lowland Rice as Affected by the Level of Control Inputs



(Source 7)

water adequacy at farm level in various locations of the system.

2.2 AN INDEX TO REPRESENT WATER AVAILABILITY IN PADDY FIELDS

The major objective of this section is to 'initiate' an analytical process aiming at the development of appropriate indicators that could be used in the monitoring of system performance in regard to irrigation

2.2. AN INDEX TO REPRESENT WATER AVAILABILITY IN PADDY FIELDS

The major objective of this section is to 'initiate' an analytical process aiming at the development of appropriate indicators that could be used in the monitoring of system performance in regard to irrigation distribution. A common approach in the economic evaluation of irrigation system performance is to compare yields in different parts of the system. Comparisons between crop seasons are also done to assess the possible improvements in system performance. However, the approach has its limitations in analyzing irrigation efficiency as the differences that can be attributed to variables not related to irrigation can be significantly high. (These non-water variables are either ignored or not adequately **separated** out.) Alternatively, onem may use the <u>volumes</u> of water delivered to different hydrologically demarcated units of the system. A cross-sectional or time series analysis of sptial aspects of water distribution could then be attempted. This approach has two major drawbacks, one is practical and the other is conceptual.

1. In a 'developing country situation' it is difficult to implement such a method because the resources required for volumetric measurements at the farm level are very high and cannot be met with the O M budgets
2. Unless daily measurements are taken and then related to the crop water requirements at different stages of growth, there is no way of representing timing effects of critical water stress.

The effect of water stress on yield may vary due to such factors as a) intensity of stress, b) stress duration, c) stage of crop growth and d) ability of the rice variety to tolerate stress. Adequate water during the total growing period is needed for vigorous growth and high yield. However, the most sensitive periods of water deficit are flowering and the second half of the vegetative period (='head development stage'). In 1969, an experiment conducted at the International Rice Research Institute (IRRI) showed that water stress imposed during different growth stages of I.R.-8, I.R.-5, and H-4 rice varieties produced different grain yields. For all varieties, the grain yield was found highest for no stress and lowest where the plants were continuously stressed throughout the growing period but not allowed to undergo permanent wilting.

The grain yield of I.R. -8 was found to be less affected by moisture stress from maximum tillering to heading stages that at other growth periods (Figure 2.2 below).

For IR-5, no growth stage was found more critical than others for susceptibility to moisture stress. But the tall variety H-4 was found more sensitive to moisture stress during the reproductive and ripening stages than at others. In an another experiment at IRRI with IR 20, yield was reduced by about 66 percent when no irrigation was applied for 63 to 102 days after seeding, i.e., during the reproduction period (Reyer and Wickham, 1973). In contrast, about an equal period of no irrigation during the early growth period, i.e., 43 to 81 days after seeding, reduced the yield by only 30 percent of the total yield. When the later stress was continued to harvest time, yield was reduced by about 92 percent. The reason suggested by the authors was that the plants have time to partly recover from stress in the early or vegetative period. When substantial stress occurs in the later stages of crop growth, obviously the recovery opportunity is less. Even though the uncertainty still prevails over the issue of how the rice plant responds to water at different stages of its growth, it can be assumed that the 'sensitivity' is higher during the reproductive phase, as compared to the vegetative phase. We know that B.G. varieties of rice grown in lightly textured Gal Oya soils can yield a response pattern somewhat different to IRRI results. In the context of the paucity of location specific information, we had no other alternative than to learn from experiments conducted elsewhere. Thus we had made an allowance for possible location specific variations and consider the ' 20 days to 70 days before harvest' period as the stress sensitive critical period.

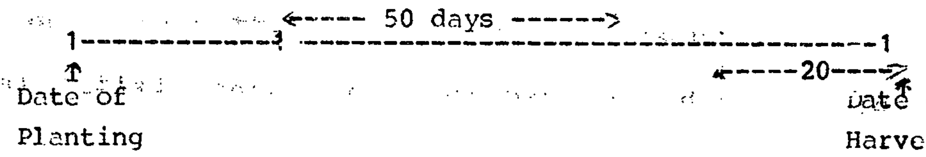
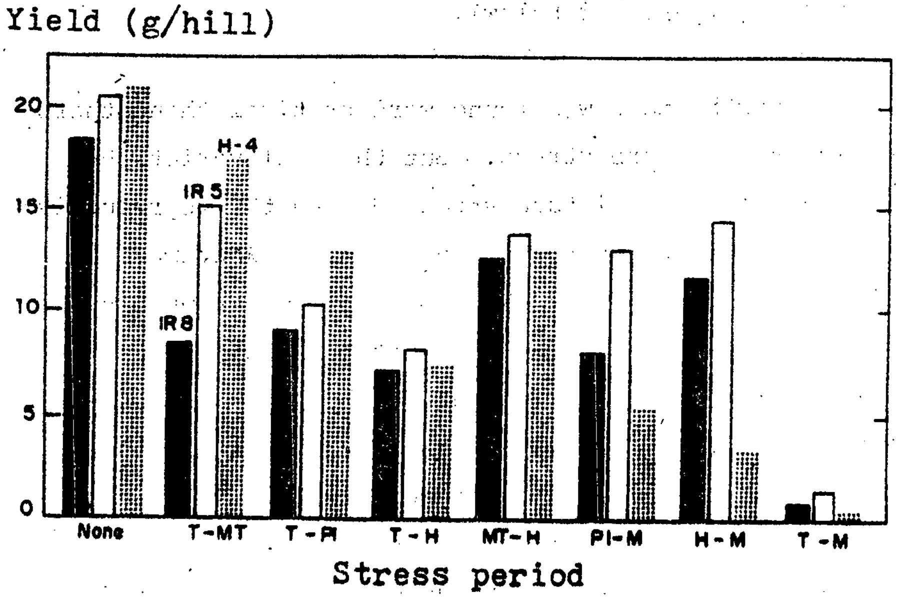


Figure 2.2: Grain Yield of Three Rice Varieties as affected by Moisture Stress at Various Physiological Growth Stages



(T = transplanting, MT = maximum tillering,
PI = panicle initiation, H = heading, M = maturity)
Source (4)

the early growth period, i.e. 43 to 81 days after seeding, reduced the yield by only 30 percent of the total yield. When the later stress was continued to harvest time, yield was reduced by about 92 percent. The reason suggested by the authors was that the plants have time to partly recover from stress in the early or vegetative period. When substantial stress occurs in the later stages of crop growth, obviously the recovery opportunity is less. Even though the uncertainty still prevails over the issue of how the rice plant responds to water at different stages of its growth, it can be assumed that the 'sensitivity' is

Measuring the adequacy of water at the farm level, or the consideration of a proxy variable that can be measured, was [illegible] next step. In other words, the logical next step would be to develop an indicator to reflect the water adequacy and timeliness at the farm level. We may emphasize the latter because the pattern of distribution of water dificit over the crop duration would be equally important as the total volume supplied. Leslie Small and Celia Capule (11) suggest five different characteristics of an ideal 'growth-related moisture index,' namely :

1. it should incorporate the <u>intensity</u> of stress ;
2. it should incorporate the rate of recovery when stress of a given intensity ends;
3. it should contain the effect (either positive or negative effect of stress) in one growth stage on the crop's ability to withstand stress in a later growth stage;
4. it should incorporate the effect of stress in one growth stage on the crop's ability to grow and develop in stressed conditions in a latter growth stage; and
5, it should be able to indicate the growth stage differences in the crop's susceptibility to stress.

Further, they claim that most stress indices are limited to the first item of information (the intensity of stress). Folbwing Hiler and Clark (1971), Small and Capule had defined their Water Shortage Index (WSI) as follows :

$$\underline{WSI} = {}^{n}_{i=1}\ \underline{(WSFi)}\ (\underline{CSi})$$

Where n is the number of growth stages
<u>[illegible]i is the water shortage factor for growth</u>
stage <u>i</u>, and ,
<u>CSi is a factor reflecting the relative susceptibility</u> of the
crop in growth stage <u>i</u> to water shortage.

Water Shortage factor for growth stage <u>i</u> was being specified as:

$$WSFi = {}_{\underline{j}=1}\ (PANi)\ (DSWi)$$ where;

PANj is the pan evaporation on day j, and
DSWJ is the scaled depth tothe perched water
table on day J.

The most striking features of this approach, as compared to conventional ones, would be the inclusion of different growth stages of rice plant and respective intensities of stress and b) the relative simplicity in measurement.

They had used pan evaporation as a proxy for potential evapotranspiration. The depth to the perched water table was measured by a perforated tube installed in the ground after land preparation has been completed. The depth to the perched water table was scaled from zero (perched water table at or above ground surface) to 1.0 (perched water table at or below the bottom of the perfor ated tube.) The bottom of the tube was at some reasonable depth with respect to the rice plant's root zone, and therefore, measured perched watertable was restricted; ground level being the upper limit (stress is minimal and equal to zero) and bottom of the tube being the lower limit (cOrresponds to a maximum stress, equal to 1). Hence, conceptually one may argue that this approach has ignored the possible contributions of standing water at verying depths. This is important in our situations as we could clearly observe such effects as the control of weeds by standing water. In addition, in regard to 'measurement', considering out resource limitations, it is questionable if we could use this approach in a situation like Gal Oya, in a large scale monitoring programme.

In our analysis we have tried to develop a water Abailability Index based on daily observations on water adequacy in selected 'Liyaddas'.[3] This is primarily based on a concept developed by Wickham and others (14). Wickham (1973) developed the concept of the stress day as an index that could be related to wetland rice yield. Initially he defined a stress day as a day the rice field is without standing water. Because the biggest proportion of stress days occur during a few prolonged drought periods, and because there is a transition between wet and dry soil, he then argued that the first few days of stress would not affect yield. The best results were obtained by omitting the 3-day period. The hydrologic basis for 3 days was that typical rice soils hold 10 mm of water in the root zone.

Evapotranspiration of 3 mm/day takes about three days before moisture is completely exploited. Hence, 'stress days' was defined as days in excess of three when the paddy is continuously without standing water. Early stress was defined as occurring from transplanting to 60 days before harvest (DBH) and late stress as occurring from 60 to 30 DBH. Using these definitions, yields were related to stress days and nitrogen fertilizer in a multiple regression equation. Since then, several studies used a similar approach (Miranda, Senen and Levine, 1976 and 1979, Tabbal and Wickham 1979, obedoja 1976, Small, Capute and Oallaver 1980, Ramchand 1982, Svendsen 1983, etc.). Experiments of this nature, especially those conducted by the IRRI researchers so far have contributed tremendously towards improvements in water management research and useful attempts towards these ends are still in progress. In our analysis, emphasis will be put on:

1. the use of simple daily observations;
2. the 'availability' of water; i.e., the varying degrees of standing water will be considered;
   instead of limiting the analysis to 'stress days',
3. the intensity of stress and availability, and
4. differences in growth stages.

First we will consider only 1 and 2 of the above four aspects. However, in Chapter 4 we will make an effort to extend out analysis to cover 3 and 4 based on observations of a single hydrological unit. 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 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.

---

[3] Liyaddas = individually bunded blocks in a paddy field. The number of liyaddas per hectare may vary from about 20 to 100.

Trained enumerators recorded for each Liyadda each day the eater status of that plot as being:

a) severe shortage of water (soil cracking)
b) moderate shortage (soil dry)
c) soil wet (no standing water)
d) standing water (shallow)
e) standing water (deep)/flowing across bunds.

The first form of index (WAI), to indicate the degree to which a farm's crop had water available to it through the growing period, 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 the 50-day period between 20 and 70 days before harvest. To calculate the index, the number of days in the first categories (a. severe shortage) were added to the number of days in the second category (b. moderate stress) which were weighted double. This outcome was then added to the number of days in the third category (c. saturation) weighted triple; and the last two categories of abundant water supply (d. standing water-shallow) and 'e' deep standing water weighted as quadruple. That is : WAT =(ax1) + (bx2) + (cx3) + (dx4) + (ex4)

Where; No. of days of I serve shortage = a, II moderate shortage = b, III soil wet = c, Ivstanding - shallow = e and V standing - deep = e.[4]

The WAI is an index and therefore it does not measure water adequacy as a thermometer measures temperature, but serves as an easily measured substitute that indicates ot represents a much more complicated and difficult to measure variable- in this case, rice plant water stress. Measuring soil moisture concentration in the field to adequately represent varying conditions is really a difficult task. Among these difficulties are 1) presence of uneven land topography resulting in the unequal wetting of soils, 2) occurrence of constant soil moisture changes which are not captured in one-time soil sample profile taken for experimentation; 3) uneven plant growth and non-uniform root distribution providing spatial variations in overall soil -moisture content; 4) presence of varying soil composition within the field due to erosion etc., resulting in changes in pore volume and bulk density, and 5) practical difficulties such as a) heavy clay soils, b) a typical conditions due to flow changes in the nearby cannals; which are highly 'localized,' etc.

The utility of the WAI or similar concepts for water management research comes precisely because it is simple, easy to measure, and cheap. Furthermore, it is a highly integrated variable reflecting the effects of PET (Potential Evapotranspiration) demand, soil hydraulic conductivity, depth to water table, bund leakage, seepage, farmer water management practices and effects of rainfall.

In that sense, it is similar to pan evaporation values which provide an <u>indicator</u> of crop <u>PET</u> rates by integrating the effects of incoming solar radiation, alledo, sensible heat flux, relative humidity, and wind run. Neither pan evaporation nor the WAI measures the phenomenon of interest directly, byt each is a convenient indicator of, in one case <u>PET</u> , and in the other, plant water stress. The WAI does account for duration of stress by summing days and in targeted at a particular period in the rice plant growth cycle that includes its most moisture-sensitive stages. It does not currently account for the different impacts on yield caused by equivalent intermittant and continuous stress periods. We will deal with this aspect in Chapter 4. Our next step would be to observe the distribution of 'water adequacy', as meaured by WAI, of different hydrological units, and at different levels within each unit. Once the WAI was calculated for each farm, an average WAI was calculated for those farms along the respective field channel. An everage WAI was also calculated for all farms sampled within distributary channel. Similarly a composite WAI was calculated for the respective subsystem. This permitted comparisons within field channels, between field channels, between distributaries and finally between subsystems.[5]

---

[4] As the differences in soil aeration cannot be so readily quantified and as no crop damage due to flooding was reported, both d) and e) above weighted the same.

2.3. SPATIAL DISTRIBUTION OF WATER

Assuming that W.A.I. would give an indication of the degree of water adequacy relative to water stress of plants in the fields, we may use this index to examine the spatial distribution of water input in the project area. A similar analysis was done in 1982 but was not based on 'hydrological units' at all levels. Thus a comparison beyond the distributary channel level was not attempted.[6]

2.3.1. Difference Between Two Seasons

Spatial distribution of WAI in the Maha and Yala seasons is illustrated in Figures 2.3 and 2.4. When the overall 'averages' are compared, a clear difference in WAI between Maha adn Yala seasons was not seen. The Average Water Availability Index for the Gal Oya Left Bank was computed from individual liyadda observations. This was 180.1. for the 1982 Yala season and 182.6 for the 1981/82 Maha season.

TABLE 2.1

Average Water Availability Indexs for Maha and Yala Seasons

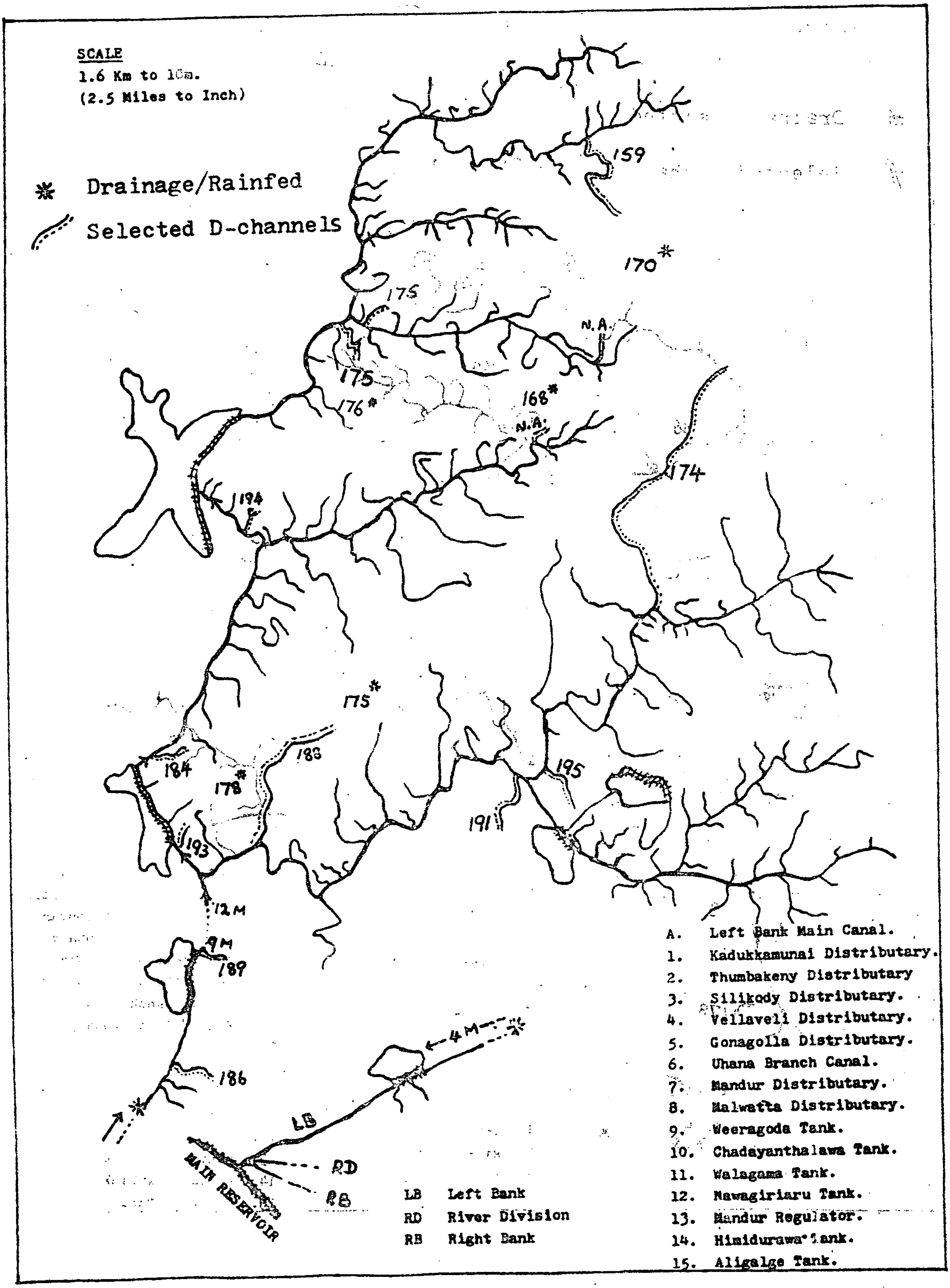
	Average W.A.I.	Standard Deviation	95 percent Confident Interval
YALA	180.1	12.8	177.2 - 183.2
MAHA	182.6	12.6	179.1 - 186.0

---

[5] Calculations were based on weighted averages. However the weighting was done on the basis of number of farms and not on the acreage.

[6] See publications 16, 17, 18 (of the list of references) for details.

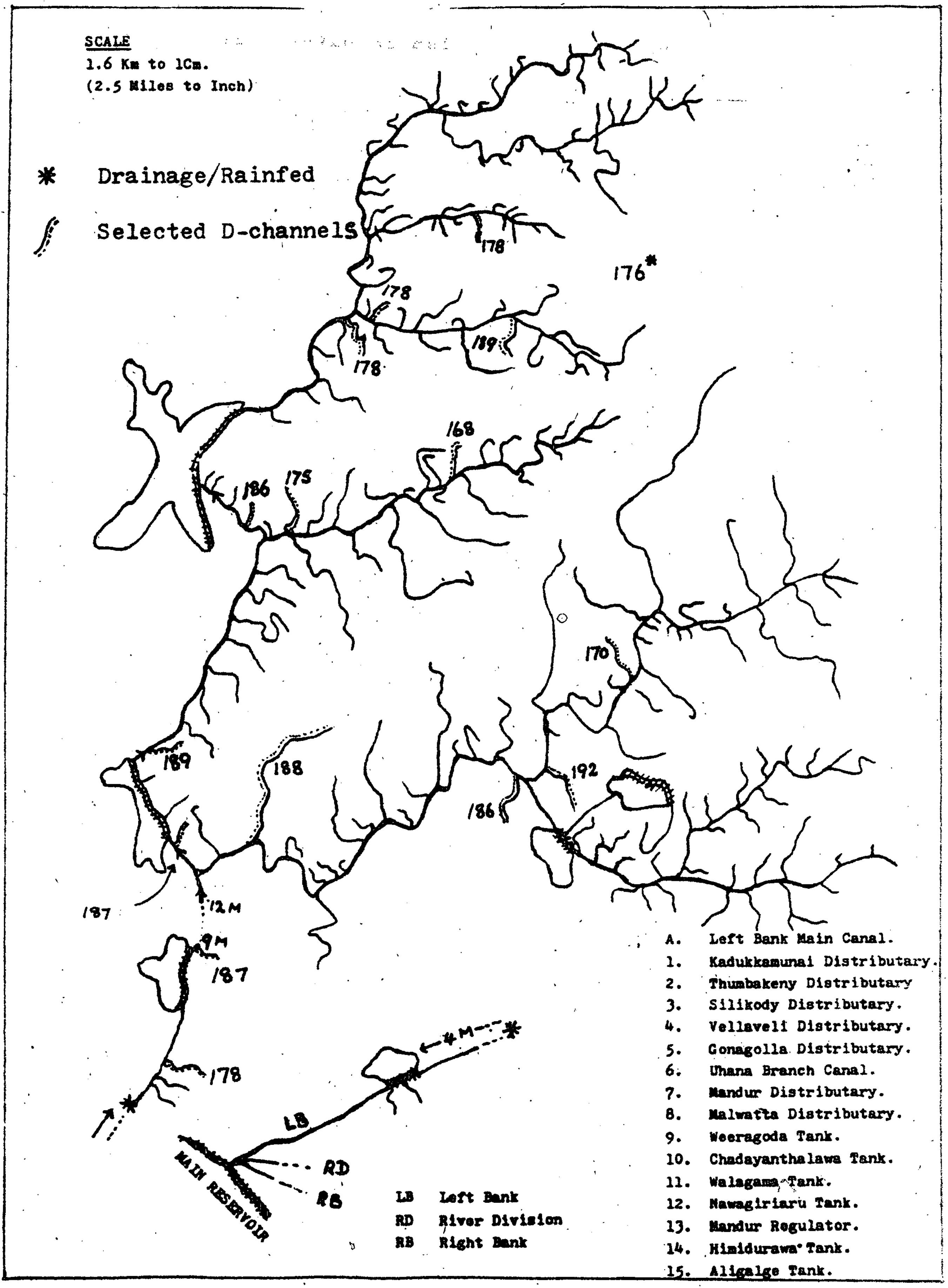
Figure 2.3: Spatial Distribution of Water 1981/82 Maha



LB Left Bank
RD River Division
RB Right Bank

A. Left Bank Main Canal.
1. Kadukkamunai Distributary.
2. Thumbakeny Distributary
3. Silikody Distributary.
4. Vellaveli Distributary.
5. Gonagolla Distributary.
6. Uhana Branch Canal.
7. Mandur Distributary.
8. Malwatta Distributary.
9. Weeragoda Tank.
10. Chadayanthalawa Tank.
11. Walagama Tank.
12. Nawagiriaru Tank.
13. Mandur Regulator.
14. Himidurawa Tank.
15. Aligalge Tank.

Figure 2.4: Spatial Distribution of Water 1982 Yala



The difference was not significant at 5 percent level. As was observed from the above table, the variability in water distribution is only slightly higher in the Yala season. However, it should be noted that the acreage under cultivation during the Yala season is signigicantly lower than that of Maha and our sample was confined to the irrigated area. Therefore, if the farm-level water availability calculations are based on 'per unit cultivable land' (instead of the land actually cultivated), the Yala season figure would be much less that what we got. However, even only the irrigated area is considered one may expect a relative 'scarcity' of water during Yala (when compared to the wet season). Therefore, it might be interesting to examine the siginificance of difference in water distribution between the seasons for a long period.

2.3.2. Differences Between Field Channels

As was from our initial analysis in 1982, there was not a significant variability in water distribution within the field channels. Some differences, however, seen in comparing WAI between head, adn tail field channels of <u>long</u> distributaries. This is even evident from field-channel wise distribution of WAI, in a distributary such as UB 2 despite the fact it is located at the head end of a branch-channel. In general, however, a) the differences between field channels and b) variation within field channels were very much less signigicant when compared to the variability between distributaries (see Tables I and II of Appendix).

2.3.3. Differences Between Distributaries

Water Availability Indexes of the distributary channels included in the sample are classified by subsystems and seasons in Table A.4 in the Appendix. It could be observed from Figures 2.3 and 2.4 and tables that, in general, the water availability in the lower distributaries of a given subsystem in lower than those located upstream of the branch channel of the same subsystem. However, given the complexity of the channel network, and the spatial distribution of the sub-tanks and major regulators, a 'head-tail' classification of the main system becomes less meaningful. We will briefly discuss this subject in the next section.

2.4 DISPARITY IN WATER AVAILABILITY : 'HEAD-TAIL' DILEMMA

The research is beginning to grasp the complexity of the irrigation system and the 'multidimensional nature' of the head-tail problem. There are several sub-tanks within the Left Bank command area. The largest among them, Navakiri tank, is not totally dependent on the supply from the Gal Oya main reservoir and has a 'reliable' catchment of its own. Thus, despite the fact that Navakiri tank is not located towards the 'head end' of the Left Bank system; the water availability of all the channels in its command area may not necessarily be lower than in the channels upstream of the system. Similarly, despite the fact that the Uhana-Mandur branch canal takes off from the 'head end' of the L.B. Main canal it does not imply that all the farmers served by this canal are better off than those at the tail end of the Left Bank main canal command. It is nearly impossible to make a rational 'head-tail' classification even within the branch-canal. Thus we observe a clear difference between the distributaries U.B. 2 (head-end of Uhana-Mandur Branch canal) and M-1 (located toward the tail end of the same Branch canal) in regard to water availability. This was evident in both 'dry' and 'wet' seasons and is indicated in the table below.

It should be noted that both U.B. 2 and M-1 are located at the head-end of their respective sub systems. The following table compares and contrasts U.B. 2 and M-1 in regard to some physical characteristics which might indicate some useful areas for extending our empirical analysis.

TABLE 2.2

Water Availability of UB 2 and M-1

Crop season	W.A.I. of UB 2	W.A.I. of M-1
1981/82 Maha	188	195
1982 Yala	188	192

TABLE 2.3

Comparison of U.B. 2 and M-1

		U.B. 2	M-1
a)	Characteristic length (Km)	5.4	1.6
b)	no. of field channels *	10	5
c)	no. of bifurcations **	24	11
d)	command area (ha)	424	176

* Excluding subdivisions, i.e. refers only to 'main branches' of the distributary.

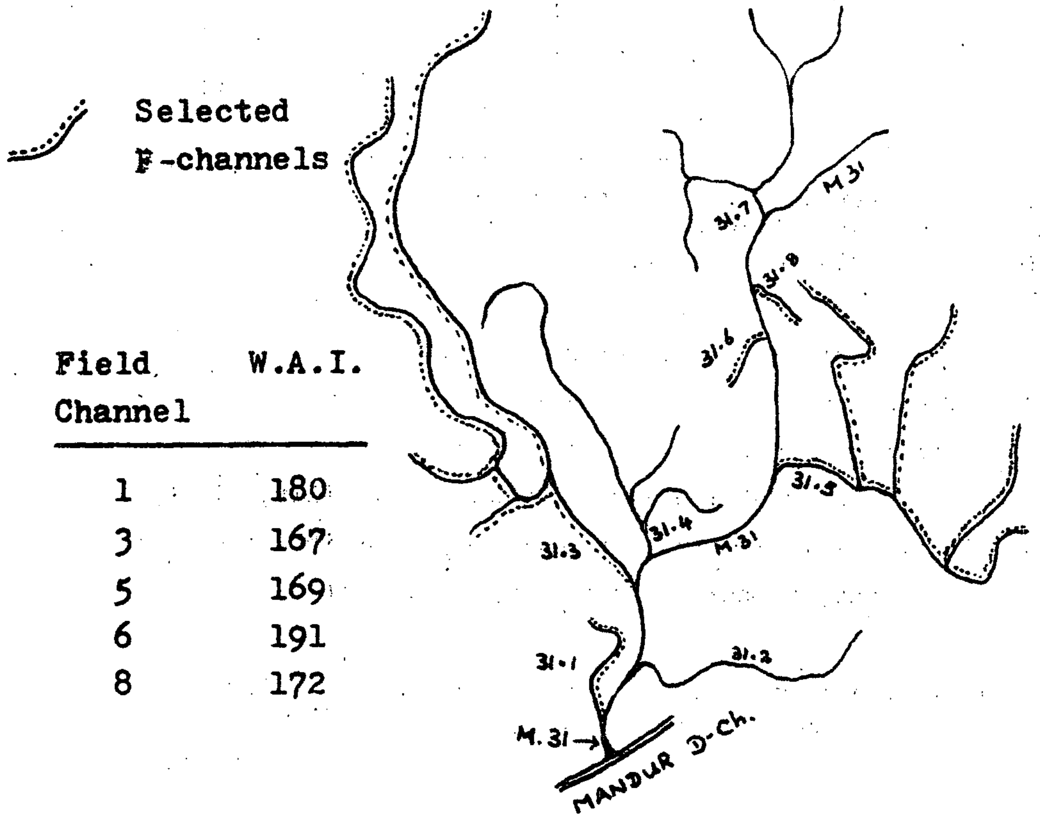
** C = (b) + subdivisions of (b).

Let us now consider the differences in water availability within a Distributary Channel by selecting a distributary channel with a large number of field channels of varying lengths. We select M-31 and Figure 2.5 shows the distribution of water availability at the field channel level. This information suggests a possible relationship between channel lengths, number of bifurcations and water availability.

Figure 2.5: Distribution of Water Within a D-channel Command
- M - 31, Maha 1981/82

relationship between channel lengths, number of bifurcations and water availability.

Figure 2.5: Distribution of Water Within a D-channel Command - M-31, Maha 1981/82



Field Channel	W.A.I.
1	180
3	167
5	169
6	191
8	172

A preliminary step towards an analysis of 'distance factors' influencing water availability, we have tested a few hypothetical functions for linear correlation.[7] These

---

[7] These functions were tested with the aid of 1980/81 data as the relevant distance variables were not readily available for 1981/82 data set. Corresponding W.A.I. values of 1980/81 were used and it should be noted that the computational procedures for W.A.I. remained unchanged. Distances were measured with the aid of project maps. Since the actual field measurements of channel lengths are now available from the I.D. "rehabilitation design surveys" this analysis is planned to be continued.

A preliminary step towards an analysis of 'distance factors' influencing water availability, we have tested a few hypothetical functions for linear correlation.[7] These include other relevant locational factors such as soil texture, elevation, drainage, size of outlets, subsystem (in which the farm is located), command areas of teh subsystem, D-channel and field channel, etd.9

In the next chapter we will examine the relationship of water availability with some selected variables important at the farm level.

hypotheses are listed below:

1. $$\text{W.A.I.} = \frac{\text{Upstream characteristic Branch channel length.}}{\text{Total effective length of the Branch Channel}}$$

2. $$\text{W.A.I.} = \frac{\text{Upstream (total) channel lengths in the ssystems.}}{\text{Total channel lengths of the subsystem}}$$

3. $$\text{W.A.I.} = \frac{\text{Upstream (total) channel length of the Distributary.}}{\text{Total characteristic length of the Distributary}}$$

4. $$\text{W.A.I.} = \frac{\text{Number of Upstream bifuracations within the ssystem.}}{\text{Total number of bifurcations in the subsystem}}$$

5. $$\text{W.A.I.} = \frac{\text{Number of Upstream bifuraotions within D-channel.}}{\text{Total number of bifurcations within D-channel}}$$

6. $$\text{W.A.I} = \frac{\text{Distance to D-channel along the field channel.}}{\text{Total characteristic length of the field channel}}$$

All these variables were specified on and individual farm basis.[8] Only the relationships 3 and 5 above were found to be statistically significant (r = 0.55 and 0.51 respectively.) This kind of analysis may be extended to ....

---

[7] These functions were tested with the aid of 1980/81 data as the relevant distance variables were not readily available for 1981/82 data set. Corresponding W.A.I. values of 1980/81 were used and it should be noted that the computational procedures for W.A.I. remained unchanged. Distances were measured with the aid of project maps. Since the actual field measurements of channel lengths are now available from the I.D. "rehabilitation design serveys" this analysis is planned to be continued.

---

8 For instance a measure such as "No.of upstream bifurcations within the D-channel" would count all the channel bifurcations from D-channel take off' to the particular farm under consideration. Similarly, "Total channel lengths in a Subsystem" indicates the aggregate total length of all the channels (including distributaries and field channels) in a subsystem.

Chapter III

IRRIGATION, LAND TENURE AND (SOME SELECTED) FARMER DECISIONS

3.1 IRRIGATION AND TENURE

Distribution of sample farmers by source of irrigation and tenurial category is given in Tables 3.1 and 3.2. As can be observed from these tables nearly 18 percent of the Maha sample and about 23 percent of the Yala sample were outside the 'owner-operator' category. The table also indicates a reduction in the drainage and rainfed categories (as sources of water for paddy production) in the Yala season. However, this may not be a true estimate as the ratio in the sample may not necessarily represent the true ratio in the population. Strinkingly, the proportion of farmers of non-owner operator category (i.e. tenants, leasees, etc.) in the drainage and rainfed classes (when aggregated) is significantly higher than the proportion of owner-operators in those classes.

Tables 3.1 and 3.2 also reveal that nearly 40 percent of the Maha sample and 23 percent of the Yala sample were either 'encroachers' or holding private lands. Not surprisingly, the proportion of encroachers and private farmers (when aggregated together) in the drainage and rainfed categories is seen to be higher than the proportion of 'regular colony operators' on those calsses.

3.2 ETHNIC GROUP CLASSIFIED BY IRRIGATION AND TENURE

Tables 3.3 to 3.4 classify ethnic group by the source of water for paddy cultivation and by renurial conditions. It is revealed from these tables that

1. In Maha 1981/82, 29 percent of Sinhala farmers and 13 percent of Tamil farmers were not served directly by the L.B. canal system. The corresponding figures for Yala 1982 were 12 percent and 21 percent respectively.

2. In the Tamil group 55 percent of farmers in Maha and 47 percent in Yala were either encroachers or private farmers. The corresponding figures for the Sinhala group were 28 percent and 15 percent respectively.

3. Proportion of farmers in the non-owner operator category was significantly higher in the Sinhala group.

3.3. WATER AVAILABILITY, FARM INCOME, FARM SIZE, AND INPUT USE

In this section an attempt is made to examine if there is any relationship exists between water availability and a) family income, farm size, and the use of farm inputs. In this analysis we have divided the sample farms into four groups based on the Water Availability Index of the individual farm namely;

TABLE 3.1

Distribution of Sample Farms by Source of Water Supply and Operator Groups (Rows = Operator Codes, Columns = Source of Water Supply)*

Key : Rows: 1= Regular colonist 2= Encroacher 3= Private Holding
Columns: I=L.B. Channel II= Drainage III= Rainfed

	MAHA				
	I	II	III	Total	%
1) Colonists	217	20	1	238	61
Row. Percent	91	8	--		
Col. Percent	71	27	8		
% of total	55	5	--		
2) Encroachers	33	22	10	65	17
Row. Percent	51	34	15		
Col. Percent	11	30	83		
% of total	9	6	3		
3) Private	54	32	1	87	22
Row. Percent	62	37	1		
Col. total	18	43	8		
% of total	14	8	--		
Col. Total	304	74	12	390	100
%	78	19	3	100	

YALA

		I	II	III	Total	%
1)	Colonists	243	12	0	255	78
	Row. Percent	95	5	--		
	Col. Percent	86	29	0		
	% of Total	74	4	--		
2)	Encroachers	13	0	0	13	4
	Row. Percent	100	--	--		
	Col.Percent	5	--	--		
	% of Total	4	---	--		
3)	Private	27	29	5	61	18
	Row. Percent	44	48	8		
	Col. Percent	9	71	100		
	% of Total	8	9	1		
	Col. Total	283	41	5	329	
	%	86	13	1	100	

* There were in the form of 4-way cross classifications. Thus only those records with answers to all the variables were included and as a result a small reduction in the sample size is observed here.

TABLE 3.2

Distribution of Sample Farms by Source of Water Supply and Tenure Group (Rows = Tenure Group, Columns = Source of Water Supply)*

Key : Rows : 1=Owner-operator 2='Ande' (sharecropper)
3=Private Holding 4= Mortgage and other
Columns : I=L.B. Channel II= Drainage III = Rainfed

MAHA

		I	II	III	Total	%
1)	Owner-Operator	263	48	11	322	83
	Row. Percent	82	15	3		
	Col. Percent	87	65	92		
	% of Total	67	12	3		
2)	Encroachers	16	12	0	28	7
	Row. Percent	57	43	--		
	Col. Percent	5	16	--		
	% of Total	4	3	--		
3)	Leaseholders	7	13	0	20	5
	Row. Percent	35	65	--		
	Col. Percent	2	18	--		
	% of Total	2	3	--		
4)	Morrgage and Other	8	1	1	20	5
	Row. Percent	90	5	5		
	Col. Percent	6	1	8		
	% of Total	5	--	---		
	Col. Total	304	74	12	390	100
	%	78	19	3	100	

(continued)

TABLE 3.2

Distribution of Sample Farms by Source of Water Supply and Tenure Group (Rows = Tenure Group, Columns = Source of Water Supply) continued

Key : Rows: 1 = Owner-Operator 2= 'Ande' (sharecropper)
3 = Private Holding 4= Mortgage and other
Columns : 1=L.B. Channel 11= Drainage 111 = Rainfed

	Yala				
	1	11	111	Total	%
1) Owner-Operator	229	25	0	254	77
Row. Percent	90	10	--		
Col. Percent	81	61	--		
% of Total	70	7	--		
2) Encroachers	12	0	1	13	4
Row. Percent	92	--	8		
Col. Percent	4	--	20		
% of Total	4	--	--		
3) Leaseholders	7	13	0	20	6
Row. Percent	35	65	--		
Col. Percent	3	32	--		
% of Total	2	4	--		
4) Mortgage and Other	35	3	4	42	13
Row. Percent	83	7	10		
Col. Percent	12	7	80		
% of Total	11	1	1		
Col Total	283	41	5	329	100
%	86	13	1	100	

TABLE 3.3

Ethnic Group Classified by Source of Water

		Tamil		Sinhala	
		Number	Percent	Number	Percent
Served by L.B. System	Yala	61	79	221	88
	Maha	141	87	161	71
Drainage	Yala	16	21	25	10
	Maha	21	13	53	24
Rainfed	Yala	N.A.	N.A.	5	2
	Maha	N.A.	N.A.	12	5

TABLE 3.4

Ethnic Group Classified by Operator Group

	Tamil		Sinhala	
	Number	Percent	Number	Percent
A) 1981/82 Maha				
Colony	73	45	163	72
Encroachers	32	20	33	15
Private	57	35	30	13
B) 1982 Yala				
Colony	41	53	213	84
Encroachers	6	8	7	3
Private	30	39	31	13

TABLE 3.5

Ethnic Group Classified by Tenure Group

Tenure Group	Ethnic Group			
	Tamil		Sinhala	
	Number	Percent	Number	Percent
A) 1981/82 Maha				
Owner Operator	143	88	177	78
'Ande' (sharecropper)	17	11	11	5
Leased holder	1	--	19	8
Mortgaged and other	1	--	19	8
B) 1982 Yal				
Owner Operator	77	100	176	70
'Ande' (sharecropper)	--	--	13	5
Leased holder	--	--	20	8
Mortgaged and other	--	--	42	17

Category I	Top 25% of farms in terms of water availability (WAI 189)
Category II	2nd quartile of farms in terms of WAI (181 - 189)
Category III	3rd quartile of farms in terms of WAI (173 - 180)
Category IV	4th qaartile of farms in terms of WAI (less than 173)

Each of the above mentioned variables were then examined according to these four categories. The results are summarized below.

3 3.1 Water Availability and Farm Incomes (Including Non-Paddy Crops)

Higher levels of water availability seem to be associated with higher levels of farm income. In the Maha season, water availability categories 1, ii, 111, adn IV reported average farm incomes of 10,383, 11,918, 13,629, and 12409 (Rupees per hectare) respectively. In the Yala season the respective figures were 8,411, 8,482, 10,648 and 10,697.

3.3.2. Water Availability and Farm size

A clear relationship between the size of the farm and its water availability was not observed from data.

TABLE 3.6
WAI and Farm Size

	Average Farm Size Maha	Average Farm Size Yala
WAI Category I	1.4	1.10
WAI Category II	1.1	1.12
WAI Category III	1.0	1.25
WAI Category IV	1.2	.99

3.3.3. Water Availability and Inpute Use (Excluding Labour)

As the per unit costs of fertilizer and other agrochemicals do not vary signigicantly between regions in the project area, cost per input is considered here for comparison purposes.1

A significant relationship between water availability and the cost of fertilizer was observed in the Yala season. Farmers having a better water supply seem to be applying more fertilizer in the season. The same is observed from the Maha season data too, with category IV as an exception. This aspect will be discussed later in this report.

TABLE 3.7

[illegible] and Fertilizer Input

	Yala	Maha
WAI Category I	731	711
WAI Category II	857	787
WAI Category III	895	873
WAI Category IV	970	745

Variability between WAI categories was not so significant in regard to the use of seed paddy[2] (quanity of seed) cost of farm power adn agrochemicals. It is difficult to draw conclusions in regard to the relationships between water availability adn the input use pattern without analysing farm data over several crop seasons. Such a study is being conducted at present.

3.4. WATER AVAILABILITY, PLANTING DATE AND FAMILY LABOUR ENGAGEMENT

Empirical analysis of the information gathered through 1981/82 Maha and 1982 Yala season's record keeping exercise reinforces the relationships between the above variables established in our initial analysis (1980 Yearbook of Water Management Research). We observed in the field that those farmers who are 'assured' of a good water supply throughtout the season and at the same time enjoy adequate water supply during preparatory period tend to stretch their land preparatory activities over a long period of time. In so doing they could (reduce the cost of hired labour and) make use of family labour to a greater extent. This is clearly evident during the Maha season. In these farms we observe a higher WAI for the 50-day critical period. In the Yala season, during which water (both from rains and from L.B. channel system) is available only for a shorter period, clearly a 'trade-off' exists between a) delaying planting date - make use of family labour to a greater extent and resulting risk of water shortage during critical period of crop growth[3] and b) early planting (if necessary with hiring more labour) and 'reduced risk' of water shortage during the critical period of crop growth.

Thus, unlike in the Maha season, in Yala one may obeserve farmers who planted lately have to face with high risk of water shortage.[4]

TABLE 3.8

WAI, Planting Date and the Use of Family Labour

	Planting Date		Family Labuur Days/Ha	
	Yala	Maha *	Yala	Maha
WAI Category I	82	86	66	59
WAI Category II	74	94	62	72
WAI Category III	70	122	50	72
WAI Category IV	67	130	56	78

* Serial numbering was used for each season, separately.

---

[1] Fertilizer is subsidized by the Government and hence the price is more or less uniform in the project area.

[2] Almost all the farms in the sample use new varieties.

[3] We assume this reflects in the WAI.

[4] In Maha, usually those who are in disadvantageous locations of the system tend to adopt early planting.

[5] See the section on yield distribution.

It was also observed that 'dry sowing' was practiced by more farmers (30 percent of total) in the Yala season than in Maha season (16 percent of total). Those who adopted this technique in the Yala season had a favourable water situation during the critical period of crop growth (WAI = 183) when compared to their colleagues who adopted 'Puddled' wet sowing technique (WAI = 177). In the Maha season the corresponding figures were 173 and 184 respectively. It should be noted that, in Maha, general preference is for'puddled wet sowing [5] but most of these farmers whose farms are either rainfed or faced with servere water shortages tend to adopt dry sowing' techniques. Usually, Gal Oya farmers prefer the 'wet method' because of its higher yield performance and better control of weeds, etc., However, with increased farmer involvement in decisions on water scheduling, one may expect them to adopt dry sowing during the Yala season in a much more organized manner, as a water saving technique.[6] As we had discussed elsewhere (19), given the total water availability to Gal Oya system over the past few decades, one may expect severe water shortages in the future, especially iwth expected improvements throught the rehabilitation programme. In such circumstances techniques like timely dry sowing in the Yala season and water saving during Maha-especially by reducing the time involved in the preparatory activities- merit due consideration. Adequacy and timeliness in the availability of required resources at the farm level (such as farm power) are essential in this regard. 'hus the individual farmer's 'resource situation' is an important factor determining his 'access' to the above mentioned inputs. Hence a careful analysis of resource conditions of the individual farmer and its influence on his farming decisions (such as planting dates/techniques, use of family/hired labour and the use of inputs) becomes imperative.

---

[6] To quote evidence from actual operations, we have seen farmers adopting water saving techniques during preparatory adn planting stages (including dry sowing) provided that timely water issues subsequent to planting is assured. See 19 - for details.

3.5 WATER AVAILABILITY CLASSIFIED BY SOURCE OF WATER, TENURIAL CONDITION AND DISTANCE TO FARM

Not surprisingly, those farms served directly by the L.B. channel system recorded a higher WAI in both seasons (180 in Yala and 184 in Maha) than the 'drainage' farms (171 and 172 respectively).

WAI was seen to be having an inverse relationship with farm to home distance. This is evident from the table below.

TABLE 3.9

WAI CLASSIFIED BY FARM TO HOME DISTANCE

Farm to Home Distance in Km	Yala Season WAI	Yala Season Number of farmers Reporting	Maha Season WAI	Maha Season Number of farmers Reporting
Leas than 0.4	183	112	184	115
o.41 - 0.80	180	70	183	62
0.81 - 1.60	177	36	178	41
1.61 - 3.20	172	19	177	33
3.21 - 8.0	167	13	173	9

WAI distribution did not show a clear variability between different tenurial categories namely owner operators, sharecroppers, leaseholders, mortgage and other categories (180,183, 171, 175 for Yala adn 180, 179, 174, and 184 for Maha, respectively.)

CHAPTER IV

INPUT-OUTPUT RELATIONS

The yield differences among paddy crops in different season, or different locations may reflect variations in the weather conditions, level of technology adoption including the use of various inputs such as fertilizer or irrigation water, location specific factors like soil type, adn management components including motivation. A careful analysis of all such factors is not attempted here. Instead, we will first try to figure out the distribution of yield in the Gal Oya Left Bank with emphasis on the relationship of this distribution to the pattern of water distribution. Then we will estimate the profitability of paddy farming at various locations of the Gal Oya Left Bank, based on the information obtained from individual plots of the sample farms. Einally an attempt is made to develop a functional relationship between yield and the two major physical inputs, namely water and fertilizer.

4.1 YIELD DISTRIBUTION IN THE SAMPLE AREAS

Per hectare yield reported throughout this chapter is based on 'crop cut' results. Two crop-cuts, each covering 16.5 x 16.5 square feet, i.e., 1/160 of an acre, were taken for each farm covered by the survey. The two crop-cuts represented the two Liyaddas randomly selected for water status observations. At the first level of analysis, the average of two crop cuts is being considered as representing the yield of the particular farm. In the second section of this chapter, when we are dealing with response function analysis, each crop-cut will be compared with the respective water availability indicator - i.e., the productivity of each Liyadda will be compared with its own water availability figure.

Once the per hectare yield for each farm was calculated for each farm, an average yield figure was calculated for these farms along the respective field channel.

An average WAI was also calculated for all farms sampled within each distributary channel. ilarly a composite yield figure was calculated for the respective subsystems. Th s, as in the case of WAI, permitted comparisons within field channels, between field channels, between distributaries and finally between subsystems.

In general, as demonstrated in Tables A.1 and A.2 of the Appendix, there was no significant relationship between yield and the location of field channels within a given distributary. If channel lengths were also coupled with the yield levels, however, one may observe a relationship. We will deal with this level of analysis in the next section.

As illustrated in Figures 4.1. to 4.4, yield among distributaries of a given sub-system and the yield between sub-systems were seen to be significant. There seems to be a general tendency for yield to decrease in distributaries when they tak- off farther away from the branch channel within the respective subsystem. In other words, despite the difficulty in the comparison of yield levels of distributaries belong to different subsystems, there exists a difference among those located within the same subsystem and this difference is observed to be related to the point of take-off the respective distributary from the branch channel.

In regard to the differences between subsystems we may observe that :

1. In general, there is a tendency of decreasing yield when one moved from head to tail along the L.B, main canal. Yala yield of subsystem 9 is an exception. Yield levels of L.B. main subsystems, namely subsys em 1, 2, 7 and 9 for 1981/82 Maha season were 3484, 3399, 2870 and 2382 (all in Kg per ha) while the respective figures for the Yala 82 season were 3692, 3498, 2568 and 2953 respectively.
2. Subsystems 1 and 2 report the highest yield levels among all the subsystems and for both seasons.[1]

---

[1] In general, subsystem 1 indicates a high degree of yield variability. Variability in yield levels is shown in Table A.3 of the appendix.

Figure 4.1: Spatial Distribution of Yield and W.A.I.-1981/82 Maha Season, Classified by Subsystem

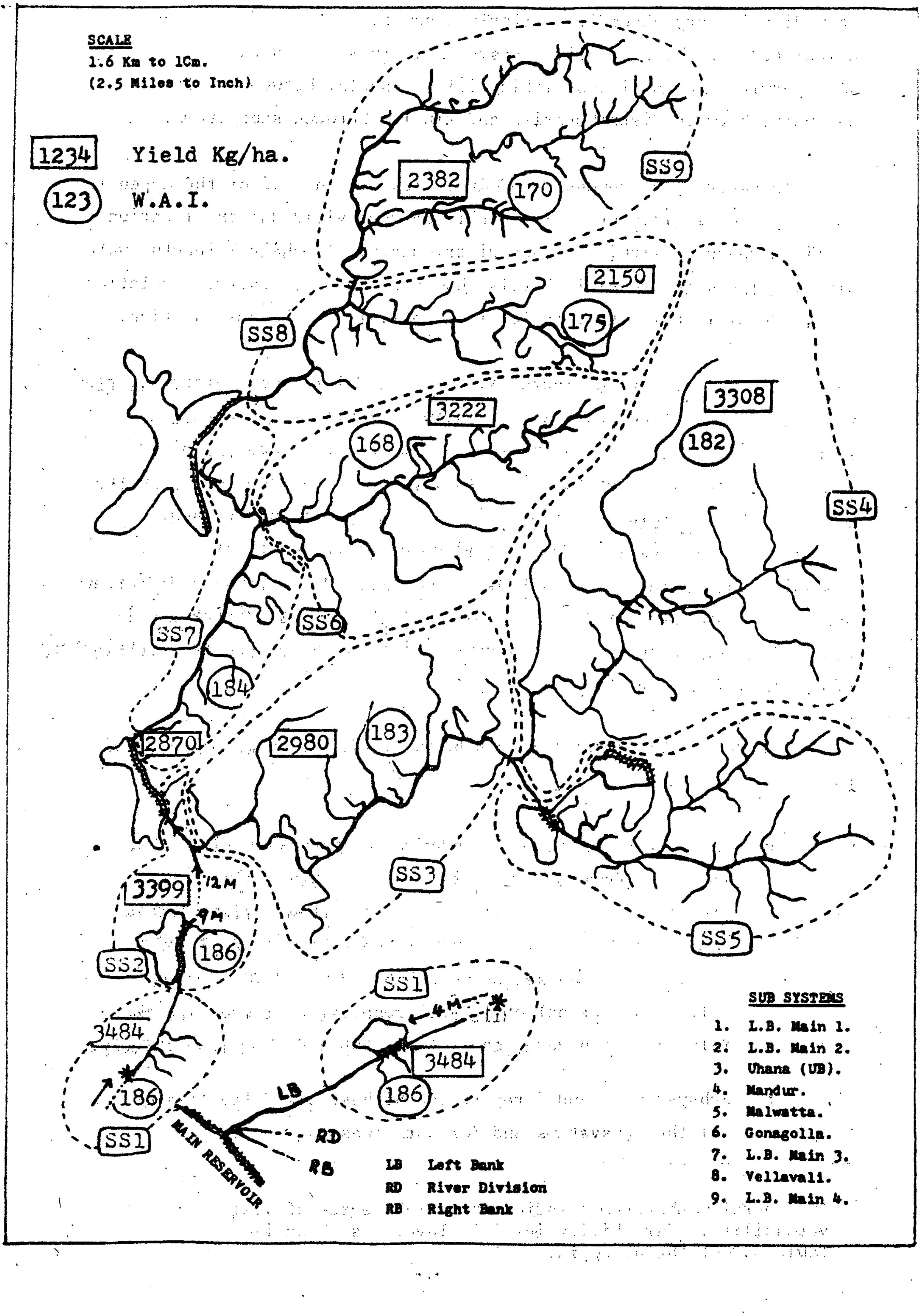


Figure 4.2: Spatial Distribution of Yield and W.A.I.-1982 Yala Season, Classified by Subsystem

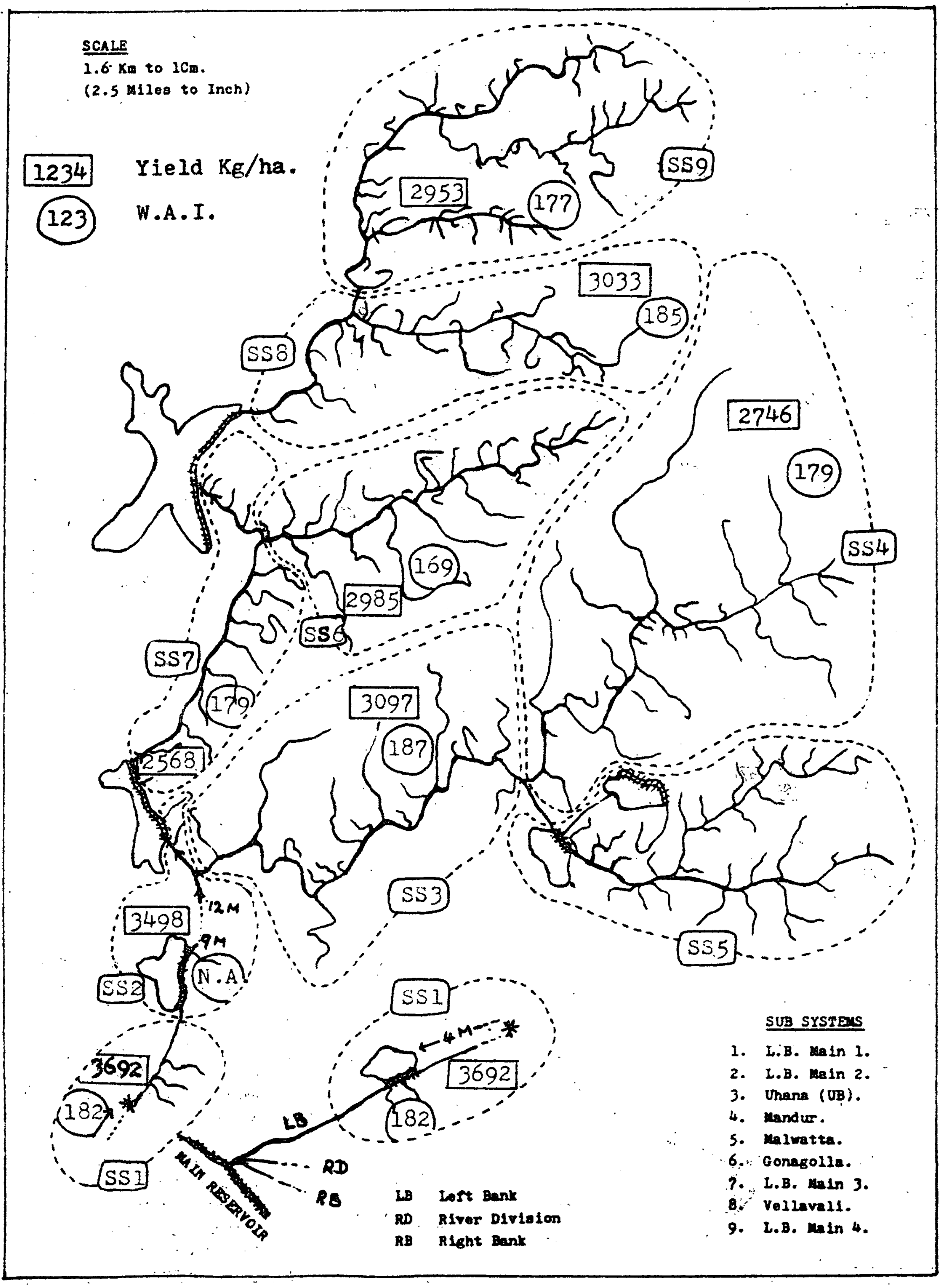


Figure 4.3: Spatial Distribution of Yield and W.A.I.-1981/82 Maha Season, Classified by D-channels

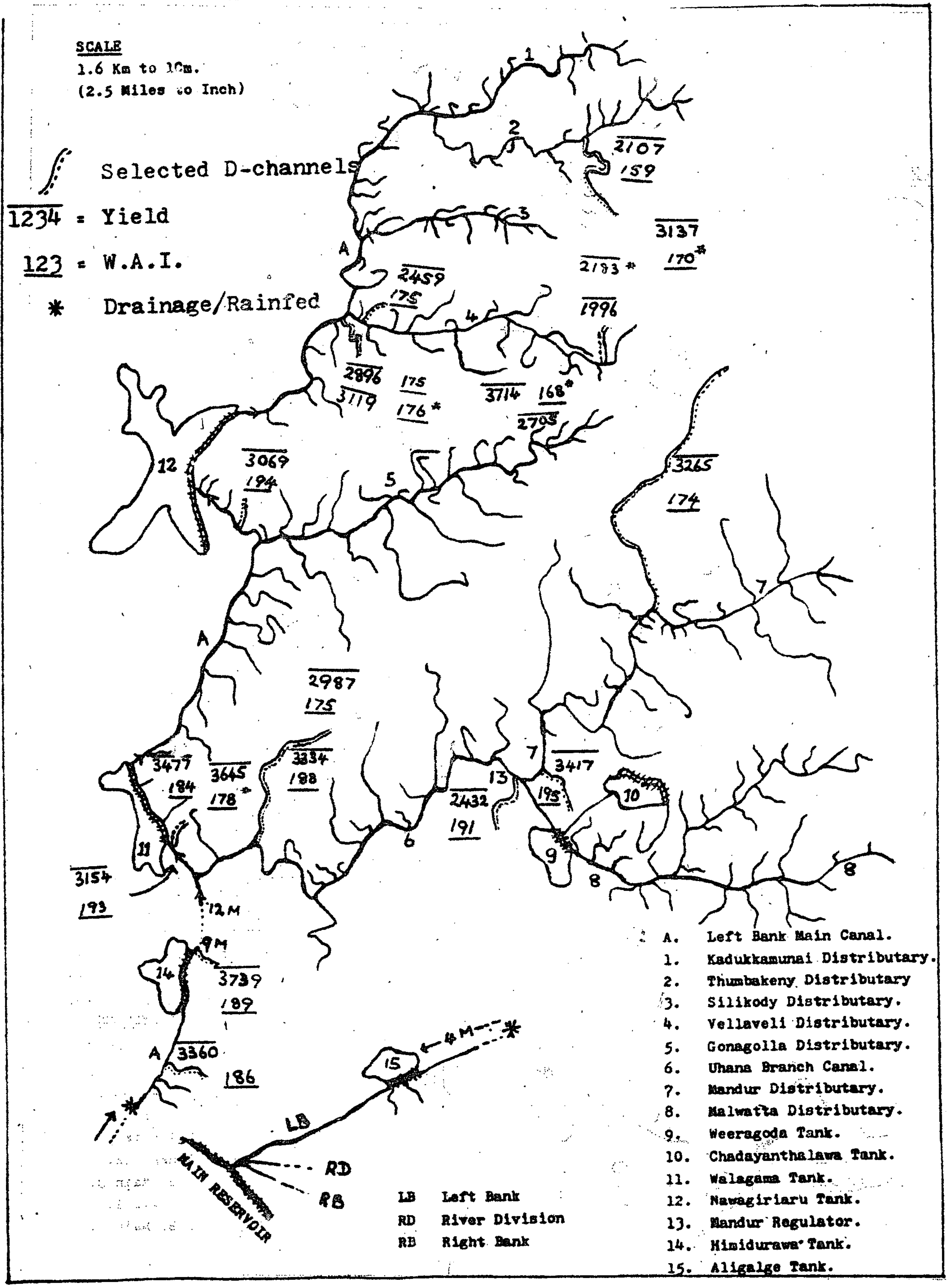
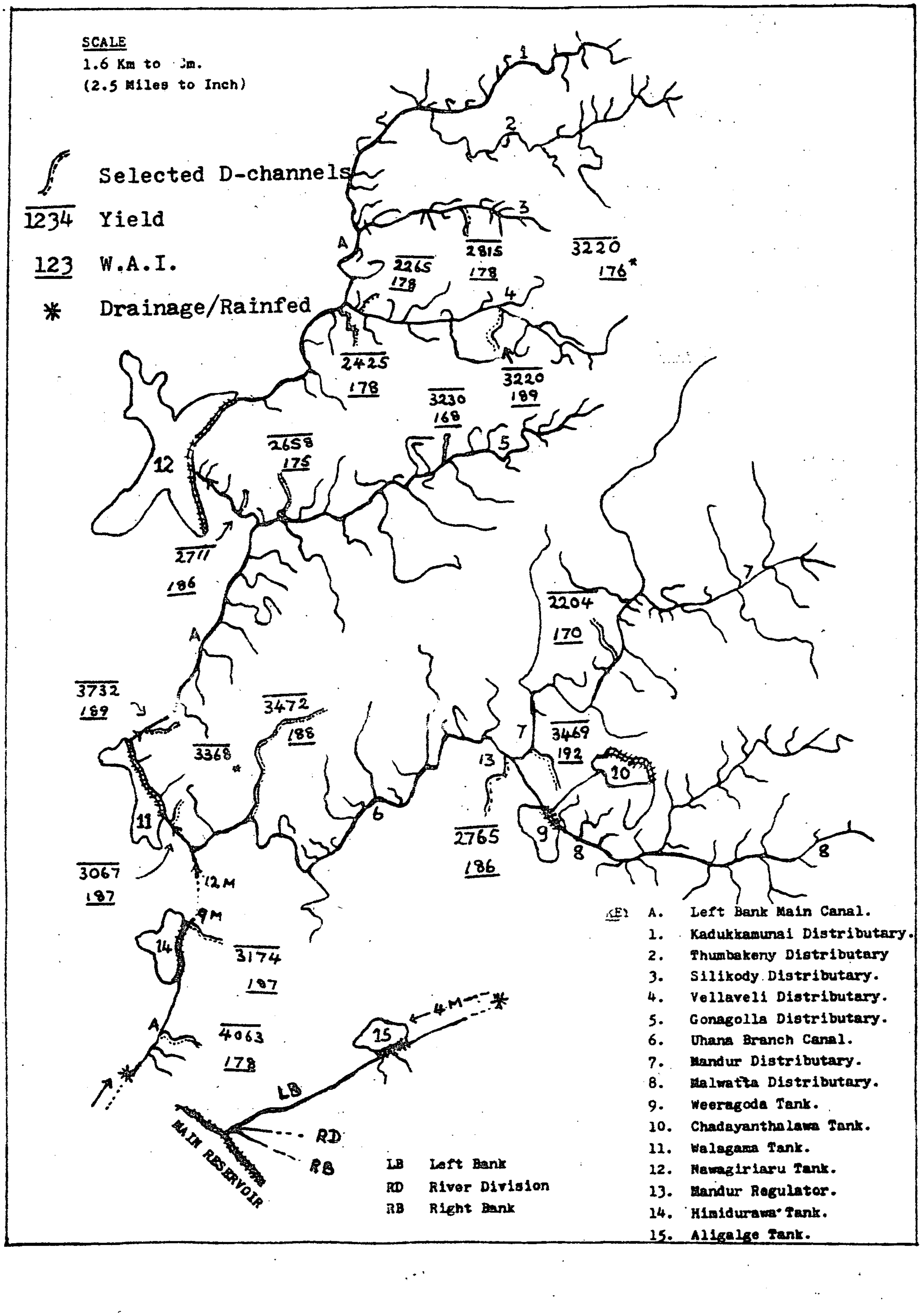


Figure 4.4: Spatial Distribution of Yield and W.A.I.-1982 Yala Season, Classified by D-channels



4.2 PROFITABILITY

This section submits the average characteristics of farming practices with respect to input use and attempts to estimate the net returns for selected factors of production. This analysis of resource use characteristics will be based on information obtained from individual farms in the sample for crop seasons of 1981/82 Maha and 82 Yala. Farming situations are described by sample averages and are classified under different subsystems. The objective is to provide in tabular form a picture of the variability of crop yields and input use for seasons and locations in Gal Oya and to provide some broad indications of the relationship between input use and resulting profits. Thus the present analysis is essentially a situation report or a profile of micro-level farming conditions and practices. We will first indicate the salient features of the computational procedures and then submit crop budgets for each subsystem.

1. Each subsystem was considered as a 'single farm' in cost computations - i.e., to obtain an average cost (per ha) figure for any given input listed below, the costs incurred by individual farmers were added together and then divided by the total area of the farms included.[2]

2. No distinction was made between colony holdings versus private and encroachments. In this respect the yield and cost structure as presented in this report may represent more accurately the average Left Bank conditions than our earlier analuses (especially that of 16 or other (Govt,) documentation).

---

[2] It should be noted that the average WAI for the subsystem (or distributary etc.) was calculated by considering the total number of farms and not on the ' area'.

3. In the cost computation, nine input categories were identified, namely; I Labour, II Farm (drought) power, III Seed material, IV Fertilizer, VI Pesticides, VII Disease control chemicals, VIII Transport and IX 'Other.' The labour input wzs further divided into four, namely I Family labour, II Hired labour, III '<u>Attan</u>' (exchange) labour and IV contract labour. In addition, farm power cost is also classified by the type - i.e., buffalo and tractor.

4. The actual cost incurred by each individual farmer in hiring labour for his own farm operations was extracted from individual farm-record sheets and was used in the calculation of the cost of production. Based on these an average wage rate was computed for each sub-system and these figures were used in the costing of family labour. As the wages for threshing operations is significantly higher than the rates paid for other operations a separate (average) wage rate for threshing was computed and the family labour cost for this operation was adjusted accordingly. As seen from the net return tables, the productivity of major factors of production, namely land, labour and capital, were calculated in two ways- both including and excluding the family labour cost.

Based on these computations a cost of production chart for the entire area was prepared. It should be noted here that subsystem 5 was not included in our recordkeeping programme. A comparison of subsystems in terms of selected input-output indicators is attempted in Tables 4.1 through 4.10.

TABLE 4.1

Estimated Average Per-hectare Cost of Paddy Production in the Left Bank System

Input Category	Cost per Hectare - Rs.			
	Maha 81/82		Yala 82	
1. Labour		3357		3850
Family	1827		2000	
Hired	1011		1223	
Exchange	503		606	
Contract	16		21	
2. Farm Power		1199		1213
Tractor	446		439	
Buffalo	753		774	
3. Seeds		803		691
4. Fertilizer		720		868
5. Weedicides		225		291
6. Pesticides		97		83
7. Disease Control Chemicals		25		10
8. Transport		99		87
9. Other		81		109
Total Cost/Ha inc FLC*		6606		7203
Total Cost Ha/exc FLC		4779		5203
Cost /Kg of Paddy inc FLC		2.22		2.36
Cost /Kg of Paddy exc FLC		1.60		1.70

* FLC = Family Labour Cost

TABLE 4.2

Cost of Production Comparison - 79/80 Maha, 81/82 Maha, 82 Yala

Input Category	Cost per Hectare - Rs. Maha 79/80		Maha 81/82		Yala 82	
1. Labour		1580		3357		3850
Family	669		1827		2000	
Hired	756		1011		1223	
Exchange	106		503		606	
Contract	49		16		21	
2. Farm Power		625		1199		1213
Tractor	272		446		439	
Buffalo	353		753		774	
3. Seeds		373		803		691
4. Fertilizer		247		720		868
5. Weedicides		114		225		291
6. Other Agro Chemicals		151		122		93
7. Other		57		180		196
Total Cost/Ha inc FLC		3147		6606		7203
Total Cost/Ha exc FLC		2477		4779		5203
Cost /Kg of Paddy inc FLC		1.84		2.22		2.36
Cost /Kg of Paddy exc FLC		1.45		1.60		1.70

TABLE 4.3

Cost of Production Classified by Subsystem – Maha 81/82

	Subsys 1	Subsys 2	Subsys 3	Subsys 4
1. Labour	3616	4048	3904	3871
2. Farm Power	1300	1423	1404	1497
3. Seeds	550	726	562	1344
4. Fertilizer	664	978	719	982
5. Weedicides	483	376	183	127
6. Pesticides	218	133	61	121
7. Disease Control Chemicals	01	44	12	04
8. Transport	130	156	132	99
9. Other	180	59	66	144
Tot. Cost/Ha inc FLC	7142	7943	7043	8189
Tot. Cost/Ha exc FLC	5414	5575	4739	5949
Cost/Kg of Paddy inc FLC	2.04	2.33	2.36	2.47
Cost /Kg of Paddy exc FLC	1.55	1.64	1.59	1.79
No. Responses (Farms)	45	45	69	55

	Subsys 6	Subsys 7	Subsys 8	Subsys 9
1. Labour	3584	2814	2400	2432
2. Farm Power	1058	1192	783	839
3. Seeds	972	542	990	817
4. Fertilizer	709	558	449	679
5. Weedicides	190	211	97	191
6. Pesticides	70	123	0	62
7. Disease Control Chemicals	117	0	02	14
8. Transport	67	103	57	43
9. Other	137	02	51	03
Tot. Cost/Ha inc FLC	6904	5545	4829	5080
Tot. Cost/Ha exc FLC	5208	4121	3389	3768
Cost/Kg of Paddy inc FLC	2.14	1.93	2.24	2.13
Cost/Kg of Paddy exc FLC	1.61	1.43	1.57	1.58
No. Responses (Farms)	57	45	55	53

TABLE 4.4

Cost of Production Classified by Subsystem - Yala 82

	Subsys 1	Subsys 2	Subsys 3	Subsys 4	
1. Labour	3584	3936	4149	4414	3376
2. FArm Power	1233	1514	1445	1390	
3. Seeds	634	864	599	534	
4. Fertilizer	643	1091	979	981	
5. Weedicides	405	430	286	259	
6. Pesticides	111	170	61	65	
7. Disease Control Chemicals	0	17	09	0	
8. Transport	93	151	137	80	
9. Other	106	176	159	87	
Tot.Cost/Ha inc FLC	6814	8149	7824	7810	
Tot. Cost/Ha exc FLC	4926	5941	5734	4866	
Cost/Kg of Paddy inc FLC	1.85	2.32	2.53	2.84	
Cost /Kg of Paddy exc FLC	1.33	1.70	1.85	1.77	
No.Responses (Farms)	38	45	41	35	

	Subsys 6	Subsys 7	Subsys 8	Subsys 9
1. Labour	3376	2956	4336	3552
2. Farm Power	1184	1051	886	1134
3. Seeds	602	631	927	819
4. Fertilizer	744	635	882	839
5. Weedicides	188	255	272	309
6. Pesticides	117	61	114	38
7. Disease Control Chemicals	0	06	34	06
8. Transport	42	65	100	26
9. Other	37	115	183	0
Tot.Cost/Ha inc FLC	6290	5775	7834	6723
Tot.Cost/Ha Exc FLC	4210	4420	5770	5219
Cost /Kg of Paddy inc FLC	2.11	2.25	2.58	2.28
Cost/Kg of Paddy exc FLC	1.41	1.72	1.90	1.76
No. Responses (Farms)	35	30	55	51

TABLE 4.5

Cost of Labour Classified by Subsystems and Season

Subsystem	Family	Exchange	Hired	Contract	Total
Subsystem 1	1728	608	1280	0	3616
Subsystem 2	2368	576	1104	0	4048
Subsystem 3	2304	560	1040	0	3904
Subsystem 4	2240	522	1098	11	3871
Subsystem 6	1696	976	912	0	3584
Subsystem 7	1424	633	677	80	2814
Subsystem 8	1440	0	928	32	2400
Subsystem 9	1312	0	1120	0	2432

Yala 81/82

Subsystem	Family	Exchange	Hired	Contract	Total
Subsystem 1	1888	448	1216	32	3584
Subsystem 2	2208	608	864	256	3936
Subsystem 3	2080	608	1440	11	4149
Subsystem 4	2944	992	467	11	4414
Subsystem 6	2080	512	784	0	3376
Subsystem 7	1355	817	784	0	2956
Subsystem 8	2064	944	1312	16	4336
Subsystem 9	1504	32	2016	0	3552

TABLE 4,6

Cost of Farm Power Classified by Subsystem and Seaso

Subsystem			Maha 81/82			Yala 82
	Tractor	Buffalo	Total	Tractor	Buffalo	Total
1	314	986	1300	481	752	1233
2	400	1023	1423	736	778	1514
3	507	896	1404	531	914	1445
4	1095	402	1497	471	919	1390
6	372	686	1058	269	915	1184
7	255	937	1192	260	791	1051
8	341	442	783	365	521	886
9	231	608	839	475	659	1134

TABLE 4.7

Returns and Profitability - Summary Sheet - 1981/82 Season

	Subsys 1	Subsys 2	Subsys 3	Subsys 4
1. Yield / Hectare	3484	3399	2980	3308
2. Income/Hectare	10452	10197	8940	9924
3. Net Income/ Ha inc FLC	3310	2254	1897	1735
4. Net Income/ exc FLC	5038	4622	4201	3975
5. Profit Rs. 100 Invst inc FLC	46	28	27	21
6. Profit/Rs 100 Invst exc FLC	93	83	89	67
7. Net Income/Man day	29	18	16	14
8. Net Returns to a Family Labour Day (exc FLC)	93	62	58	57

	Subsys 6	Subsys 7	Subsys 8	Subsys 9
1. Yield/Hectare	3222	2870	2150	2382
2. Income/Hectare	9666	8610	6450	7146
3. Net Income/ Ha inc FLC	2762	3065	1621	2066
4. Net Income/ exc FLC	4458	4489	3061	3378
5. Profit Rs.100 Invst inc FLC	40	55	34	41
6. Profit/Rs.100 Invst exc FLC	86	109	90	90
7. Net Income/ Man Day	25	35	22	27
8. Net Returns to a Family Labour Day (exc FLC)	84	101	68	82

TABLE 4.8

RETURNS AND PROFITABILITY - SUMMARY SHEET - 82 Yala Season

	Subsys 1	Subsys 2	Subsys 3	Subsys 4
1. Yield/Hectare	3692	3498	3097	2746
2. Income/Hectare	11482	10879	9632	8540
3. Net Income/ Ha inc FLC	4668	2730	1808	730
4. Net Income/ exc FLC	6556	4938	3898	3674
5. Profit Rs. 100 Invst inc FLC	69	34	23	09
6. Profit/Rs.100 Invst exc FLC	133	83	68	76
7. Net Income/ Man day	42	22	14	05
8. Net Returns to a Family Labour Day (exc FLC)	111	72	60	40

	Subsys 6	Subsys 7	Subsys 8	Subsys 9
1. Yield/Hectare	2985	2568	3033	2953
2. Income/Hectare	9283	7986	9433	9184
3. Net Income/ Ha inc FLC	2993	2211	1593	2461
4. Net Income/ exc FLC	5073	3566	3063	3965
5. Profit Rs.100 Invst inc FLC	48	38	20	37
6. Profit/Rs.100 Invst exc FLC	120	81	63	47
7. Net Income/ Man day	28	24	12	22
8. Net Returns to a Family Labour Day (exc FLC)	78	84	57	84

TABLE 4.9

Subsystems Classified by Yield, Cost of Selected Inputs and Productivity Indicators

Maha, 81/82

Subsystem	Total cost of Labour	Cost of Fertilizer	Farm Power	Total Cost Inc FLC	Exc FLC
1	M	M	M	M	H
2	H	H	H	H	H
3	H	M	H	M	M
4	H	H	H	H	H
6	M	M	M	M	H
7	L	L	M	L	M
8	L	L	L	L	L
9	L	M	L	L	L

Subsystem	Yield Kg/Ha	Net Income/Ha Inc FLC	Net Income/Ha Exc FLC	Net Returns Rs.100 Exc FLC	WAI
1	H	H	H	H	H
2	H	M	H	M	H
3	M	L	M	M	H
4	H	L	L	L	H
6	M	M	H	M	L
7	M	H	H	H	H
8	L	L	L	H	L
9	L	L	L	H	L

H= HIgh,
M= Medium
L= Low

TABLE 4.10

Subsystems Classified by Tield, Cost of Selected Inputs and Productivity Indicators - Yala, 82

Subsystem	Total Cost of Labour	Cost of Fertilizer	Farm Power	Total Cost	
				Inc FLC	Exc FLC
1	M	L	M	M	M
2	M	H	H	H	H
3	H	H	H	H	H
4	H	H	H	H	M
6	M	M	M	M	L
7	L	L	M	L	L
8	H	H	L	H	H
9	M	M	H	M	M

Subsystem	Yield Kg/Ha	Net Income/Ha Inc FLC	Net Income/Ha Exc FLC	Net Returns Rs.100 Investment Exc FLC	WAI
1	H	H	H	H	H
2	H	H	H	M	H
3	H	M	M	M	L
4	M	L	L	M	M
6	M	H	H	H	L
7	L	M	L	M	M
8	H	M	L	L	H
9	M	M	M	L	M

H = High, M = Medium, L = Low

4.3 WATER AVAILABILITY AND FARM PRODUCTIVITY

The major objective of this section is to a) briefly examine the relationship between the degree of water availability (as 'measured' by WAI) at the farm level and farm productivity and and b) explore the possibilities of incorporating cumulatuve stress effects to WAI. To attain the first objective we will use spatial distribution Charts of WAI and farm yield. Following Barker (2, 1980), we have adopted a similar methodology in an earlieranalysis (12) and the present one is an extension of those earlier efforts. In regard to the second objective (b above) we will select a specific location, attempt to incorporate both the cumulative water stress and the possible differential effects during early and late periods of crop growth.

One cannot expect there to be a perfect relationship between yield and water availability because yield is affected by factors onther than water availability, (e.g., farm size, fertilizer usage, crop care, soil quality, quality of other inputs including management, etc.) and these factors could dilute any real relation between water and yield. Still, with this said, some rather definite, if gross, relationships become evident in this analysis and are illustrated in Figures 4.5, 4.6 and 4.7.

First of all, as observed in Figures 4.5,4.6 4.7 and in Tables A.1 and A.2 of the appendix, there was no significant correlation between a) mean yield/mean WAI and the location of along the field channel. The location of field channels along the distributary also did not appear to influence the level of yield/WAI of farms along the respective field channels whether they were head, middle or tail.[3] However, as expected, both the mean yield and mean WAI of distributaries located at the tail of a given subsystem were observed to be lower than the respective figures for those distributaries located upstream of the branch canal. This can be observed in Figures 4.3 and 4.4; Fignres 4.1 and 4.2 illustrates the mean WAI and mean yield distribution for subsystems. All these are indicative of a relationship between yield and WAI.

As indicated at the outset an important objective of this chapter is to make an effort to improve WAI. In the light of the above discussion, despite the fact that so many factors other than water could affect the ultimate farm yield, we will assume that water is an important factor influencing farm yield. Based on this assumption we may test the relative efficiency of alternative indicators. The technique used here is the response function approach. In this approach usually a causal relationship between inputs and the crop yield is hypothesized. That is production is considered as a transformation of inputs into an output. Such a transformation can conveniently be described as a functional relationship.

Figure 4.5: Mean W.A.I. and Mean Yield of Field Channels - Maha 1981/82 -

'Field Channel Label' is atached to each observation. Respective subsystem number and D-channel number is included in each 'Field channel label'.

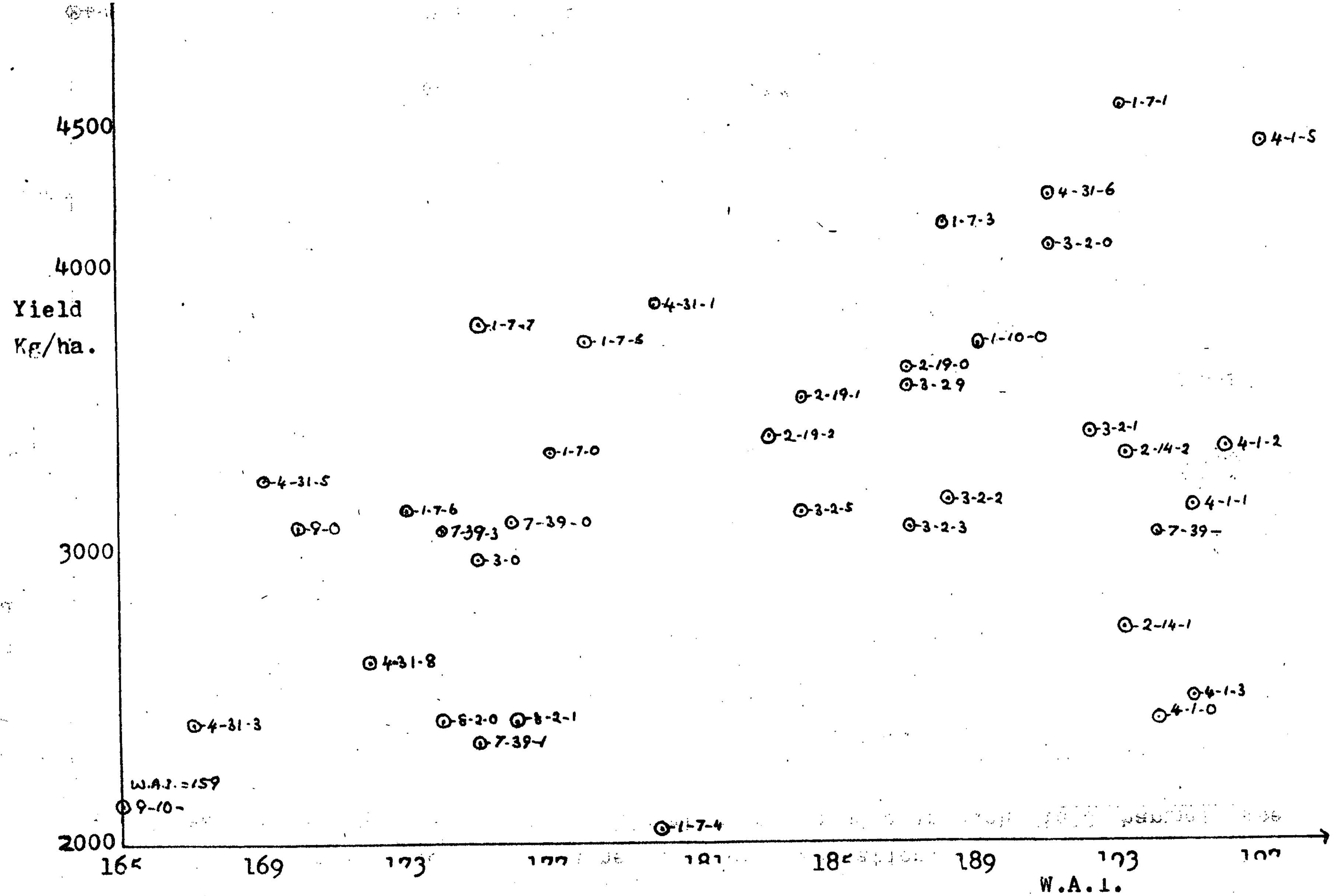


Figure 4.6: Mean W.A.I. and Mean Yield of Field Channels - Yala 1982

'Field Channel Label' is attached to each observation.

Respective Subsystem & D-channel number is included in each <u>Field channel label.</u>

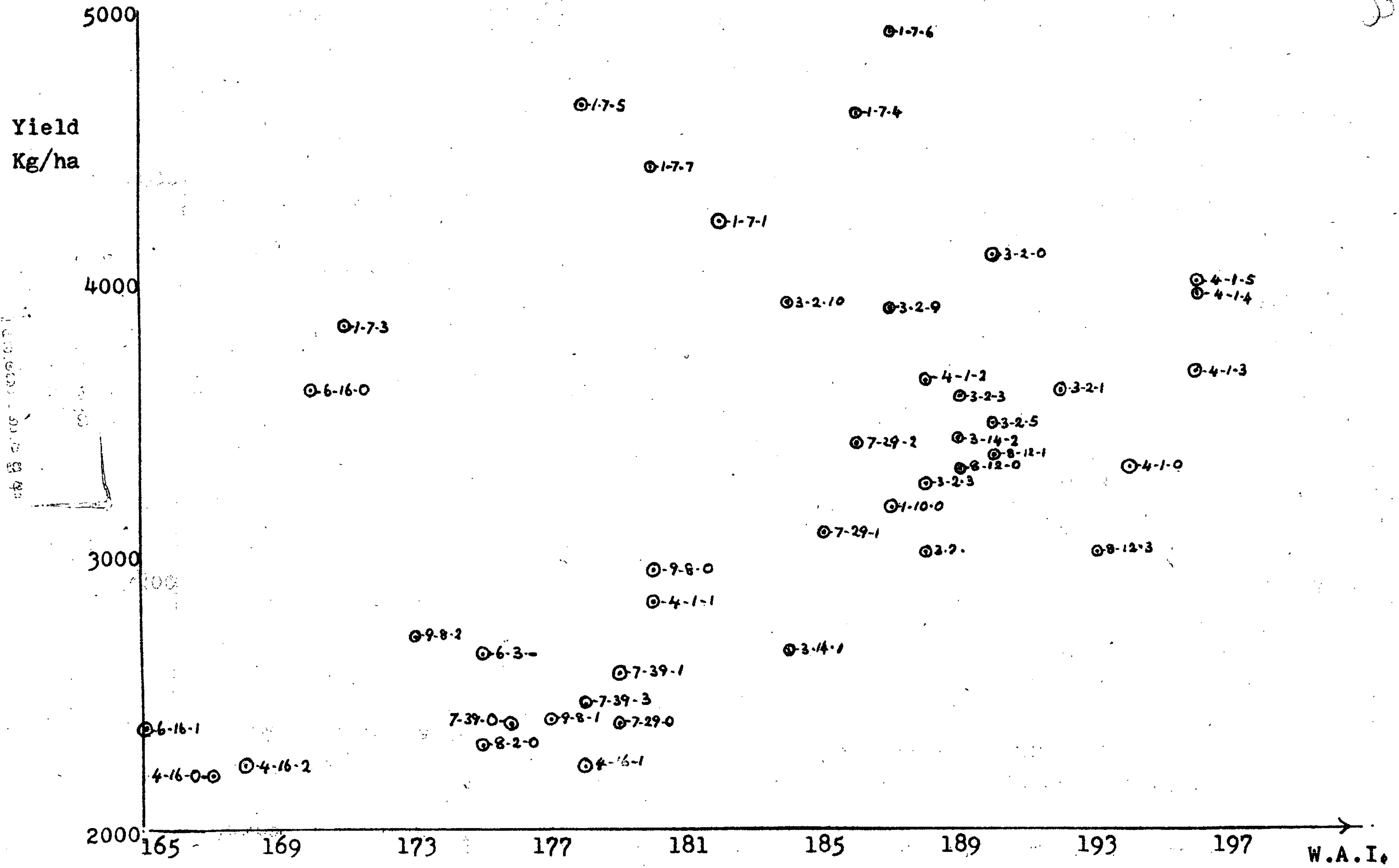
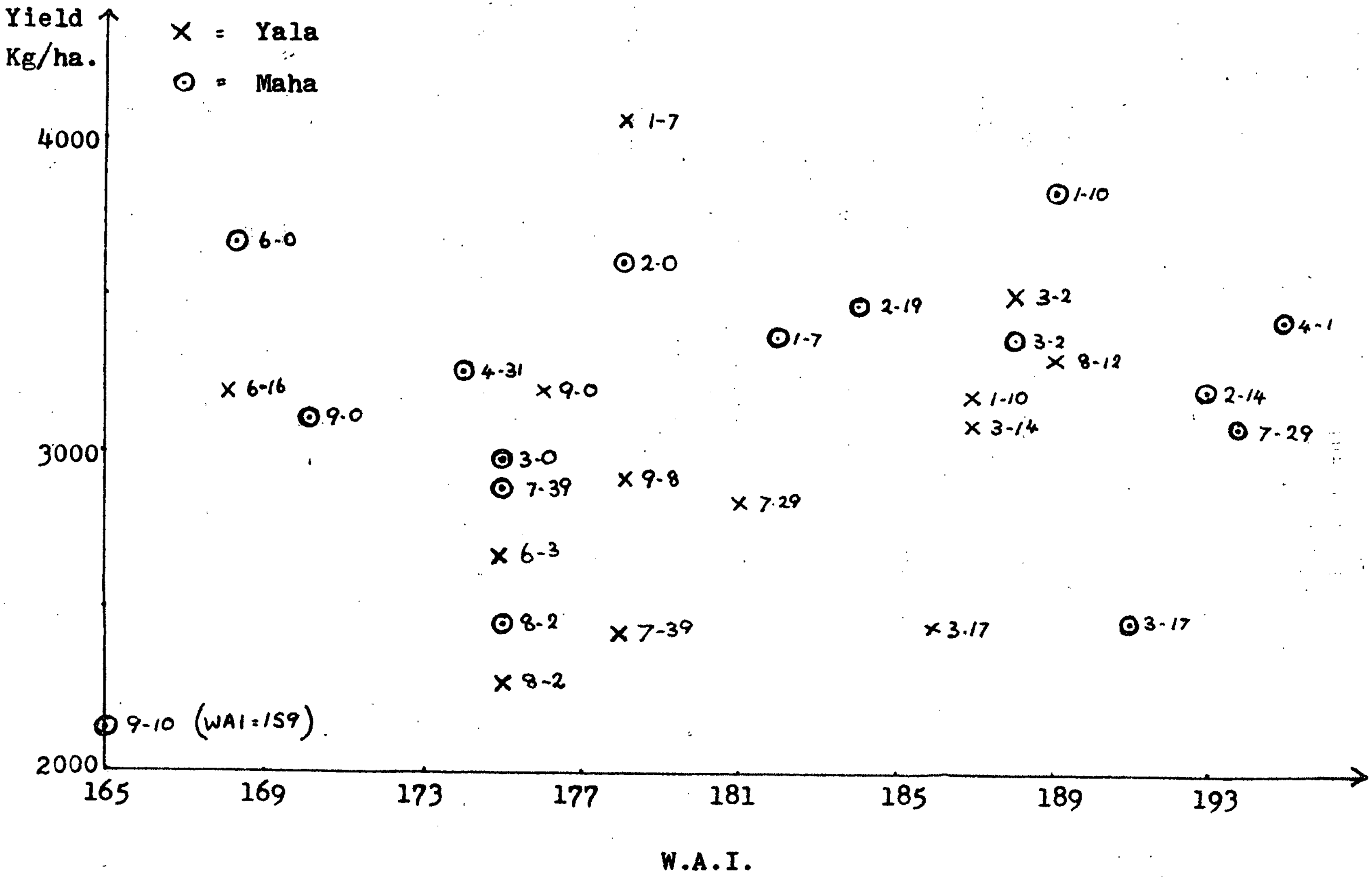


Figure 4.7: Mean W.A.I. and Mean Yield of Distributary Channels, Maha 1981/82 and Yala 1982

'D-channel label' is attached to each observation. Respective subsystem number is included in each 'D-channel label'.



Thus a production function is usually expressed in the following manner:

$$Y = f(x_1, x_2, ...xi)$$

Where Y denotes output (yield) and x's denote i inputs. In this case first we assume yield is a function of water availability (as measured by an appropriate index) and then we will add fertilizer input too. On one hand, ignoring relevant variables will bias the estimates of the regression coefficients (mis-specification error); on the other, the inclusion of an irrelevant variable will enlarge the variance, reduce the degrees of freedom, increases the possibility of multicollinearity. This could ultimately lead to biased estimates of parameters and possibly induce auto-correlated residuals. In the equations fitted in this analysis the coefficients are estimated with the Ordinary Least Squares estimation method (OLS) and this is restricted by the following assumptions:

1 The expected value of the error term is zero;

II The covariance between the error term associated with one value of the variable and that associated with any other value is zero.

III The variance of the error term associated with one value of the variable is the same with the variance associated with any other value.

IV The covariance between the error term and each of the regressors is zero.

Thus a normal distribution is assumed in regard to the error term. In addition in this model all the 'measurements' are assumed to be perfect. Obviously this model does not indicate to us the causal relationships.

---

3 Throughout our analysis, except for the individual farms, we use an average WAI (not adjusted for farm size) to indicate water availability at various levels. Thus this is used only as a proxy and not as a true composite index. Mean yields, on the other hand, are adjusted for farm size differences.

'Better fit' may be a necessary but not a sufficient condition for the assumed relationship to exist in the real world. We may also note the limitations in regard to the representations of the indicators and their accuracy. As we shall see later, alrernative WAI indicators by no means could be regarded as true indicators of water availability. Our objective is to develop a simple indicator which does not involve rigorous computations and more than that we want this to be based on easily observable field conditions. In regard to per hectare yield indicators it should be noted here that almost all of the colonists have added land, of varying extent, to their operational holding. This makes it difficult to estimate the actual size of hildings with 100% accuracy.[4] However, these aditions are not significant in terms of extent added and as far as possible adjustments were made accordingly. The seasons under reference are the 5th and 6th seasons of the recordkeeping programme, therefore one may assume that the errors in measurement in regard to variables such as yield have been minimized to a greater extent by making use of the field experience gathered during the past few years.

In this section, we have decided to deal with a subset of data for convenience in handling. We selected the command area of the distributary M-31 because it shows a higher degree of variability in regard to a) WAI. b) yield, and c) physical characteristics such as, the lengths of field channels. In future analysis we may extend the area of coverage. Distribution of water availability within M-31 command area is given in Figure 2.5.[5] We will briefly indicate below the procedure adopted in developing alternative indicators of water availability.

---

[4] An attempt was made to measure the sample holdings; but we failed to complete this exercise due to lack of resources.

[5] We consider only 1981/82 Maha season as there was no cultivation in the Yala season.

1. Two growth periods, namely *early* and *late* were identified.

```
<----'x' days---- <------50 days------> <---20 days--->
I----------------I---------------------I--------------I
Date of Planting                                Date of Harvest
```

'X' day period = early stage

50 day period = late stage

The number of a) severe stress, b) moderate stress, c) soil saturation, d) shallow water, e) deep water days during the period X was adjusted for the differences among farms by multiplying each observation of a,b,c,d, and e, by a factor $X_{ij}/\bar{x}$ where X_{ij}=ith observation in jth farm i=a,b,c,d,e, and j=i...78. *Each Liyadda was considered as a separate farm*, and the crop cut of this Liyadda was considered as the yield of that '*farm.*'

2. *Computing the cumulative effect of stress* : No distinction was made between severe and moderate stress. Instead severe stress and moderate stress days were added together to form a single variable, namely stress days and, in addition, a separate variable was created to indicate the cumulative number of days of stress. For instance, consider a hypothetical situation as follows :

XXX X XXXX XX, where X represents a day of stress. Thus, for this particular farm the cumulative stress effect was taken as 6. That is, cumulative effect was counted from the second day (of stress) onward.

3. Alternative indicators of water availability :

A large number of alternatives were tried and among then were the following :

1 Stress (days) + cumulative effect (days) = stress - 1

11 Stress + (cumulative days X 0.5) = stress - 2

111 Standing water[6] + saturation

IV(Standing water X 2) + saturation

V (Standing water X 1.5)+ saturation

VI = (V - 1)

VII = (V - 2)

VIII = (IV - 1)

IX = (IV - 2) etc. that in combinations of I,II and III, IV and V.

This procedure was adopted due to the paucity of technical information on the cumulative effect of stress.

4. Fertilizer input was measured in terms of "total Kg of nutrients per Ha". Farmers had used a variety of fertilizer mixtures, namely, I Top dressing mixture (T.D.M.), II 'V_1' mixture, III Ammonium Sulphate and IV Urea. Fertilizer input was not measured for individual Liyadda, therefore at the second level of analysis an average WAI for the entire farm was computed and the mean yield of farm was regressed on fertilizer input and the average WAI.

Some basic statistics on water status - as indicated by the above mentioned variables - fertilizer use and yield are given in the following table :

---

[6] No distinction was made between shallow and deep.

As mentioned earlier, the selection of variables and functional form was based on scatter plots and simple correlation coefficients. Some relevant correlation coefficients are given below:

	x_1	x_2	x_3	x_4
Yield	0.595	- 0.539	.173	- .165

Where X_1 = late saturation + (standing water x 2)

X_2 = late cumulative effect + stress days

X_3 = early saturation + (standing water x 2)

X_4 = early cumulative effect + stress days

TABLE 4.11

Water Status and Fertilizer Use - M 31 Distributary Command Area

Variable	Mean	std.Dev.	No. of 'Farms'
1. Early Stress (days)	5.4	6.3	78
Cumulative effect	4.7	5.9	78
Early, saturation (days)	28.5	6.1	78
Early, stand.water (days)	6.0	4.5	78
2. Late stress (days)	3.4	4.8	78
Cumulative effect	2.8	4.2	78
Early, saturation (days)	19.9	10.4	78
Early, stand. water(days)	26.7	12.7	78
3. Fertilizer-nutrients Kg/ha	132.2	27.0	39
4. Yield Kg/ha	3073.8	1209.0	78

Water Availability Indexes for the two periods were then developed and the corelation coefficients and the computational procedure are given below :

WAI I = $X_1 - X_2$, for <u>late period</u>

WAI II = $X_3 - X_4$, for <u>early. period</u> and

Correlation, yield and WAI I = .607

Correlation, Yield and WAII I = .177

As illustrated by Figure 4.8, an increasing function was observed between water (as measured by WAI) and yield. It may not be correct to interpret this as on the average "farms in M-31 command area acre in the first stage of the production function. ." Because, one could argue that the analyst, a) by limiting the period of observation to a (50 + 30) day period, and b) by setting an upper limit on the variable,[7] did not allow the diminishing and / or decreasing 'returns' portions of the classical function to occur. In addition one should bear in mind that rice plant can tolerate a wide range of standing water before it becomes destructive in terms of yield. In general, the response curve is quite different from the usual crop production functions, and even if water production functions are derived based on highly controlled experimental conditions, a meaningful interpretation of coefficients may be a difficult task (see Figure A.1 of Appendix). Having these in mind let us now observe the regression results.

Model I

$Y =$

Where y = yield Kg/ha, x_1, = WAI 1 (late period)

Result : $$y = 1467 + 11.1X_1 + .171X^2$$
$$(1.64^{**}) \qquad (1.18^{**})$$

** = significant at 0.05 level
R^2 = 0.38 Durbin Watsun statistic = 1.8

Model II $Y =$

y = yield Kg/ha, X_1 = WAI(late) X_2 = WAI (early)

Result : $$y = 1288 + 25.4X_1 + 2.7X_2$$
$$(2.34^{**}) \qquad (0.21)$$

X_2 was not significant, R^2 = 28; Durbin Watsun Statistics = 1.82

---

[7] This can be explained by considering our "old WAI" which is analogous to present ones. Even if a farm had standing water status throughout the period of crop growth under considered it will end up with a WAI score of 200 and by no means this could be regarded as a harmful situation. Thus anything below 200 may be 'sub optimal'.

These results suggest that much of the yield variability due to water availability is explained by the later water status. Further this give us an indication of the asefulness of an indicator like WAI in the 'assessment' of water distribution at the field level. In addition it was evident that nearly 40 percent of yield varibility is explained by water availability and this might be even higher if the measurement was based on volumetric readings.

At this stage an attempt was being made to incorporate fertilizer variable.[8] Average fertilizer application was 132 Kg of nutrients per hectare (std.dev. 27). It may be interesting to note here that this amound is about two thirds of the requirement. Relevant correlation coefficients are given below.

Fertilizer and Yield	0.242
Fertilizer and WAI (late)	0.267
Fertilizer and WAI (early)	0.324

Thus we may observe that the "statistical" relationship between yield and fertilizer is low. Several functional farms, including interactive terms, were tested but none of then was significant.

Example; $Y =$

$Y =$ yield Kg/ha $X_1 =$ W.A.I. (late)

$X_2 =$ WAI (early), $X_3 =$ fertilizer Kg/ha

Result: $y = 878 + 25X_1 + .802X_2 + 3.75X_3$

(2.25**) (.06) (.73)

$R_2 = 28$, Durbin Watsun Statistics = 1.75

In another model we regressed mean yield of the farm (that is Liyadda averages) on the mean WAI[9] (late) and the results is given below:

---

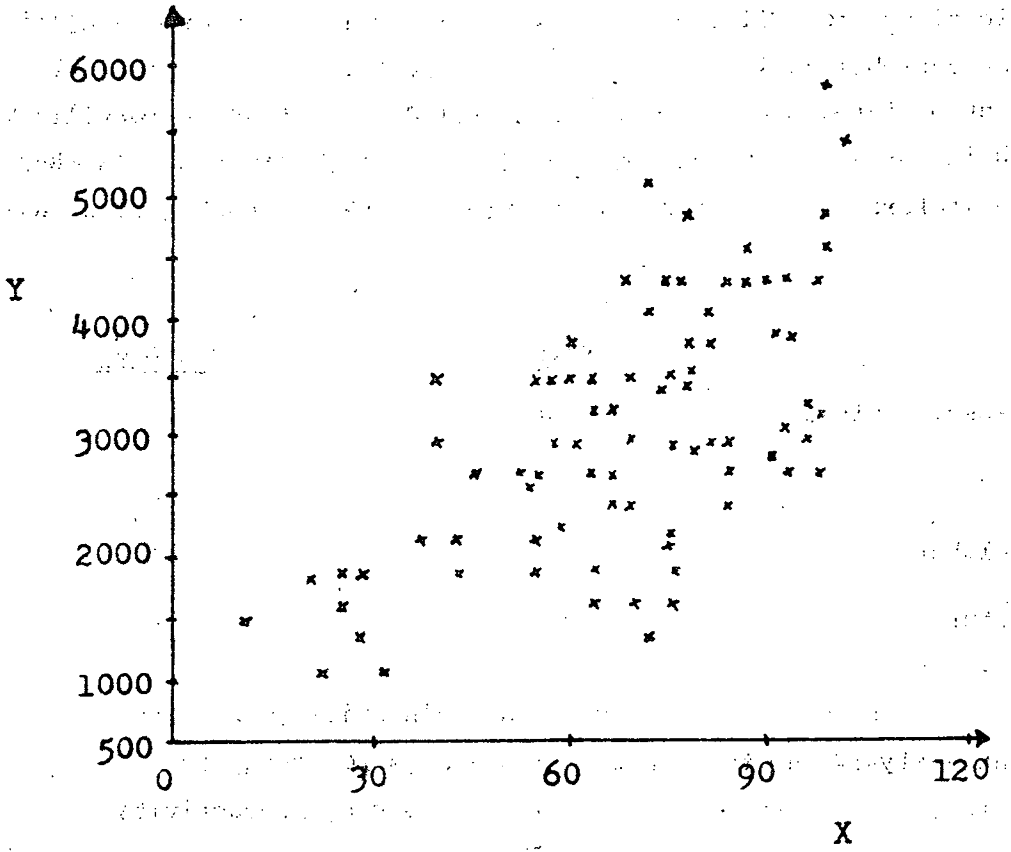
[8] Results obtained in regard to the relationships of a) yield and fertilizer and b) yield and water are consistent with those obtained earlier.(16)

[9] Mean WAI (late) = 1/2 (WAI late Liyadda 1 + WAI late Liyadda ^{2})

Figure 4.8: Yield - W.A.I. Scatterplot for Liyadda Samples in M-31 Distributary

Y = "Liyadda" yield Kg/ha.

X = W.A.I. (late) for Liyadda.



Model : $Y + B_O + B_1$ WAI
Result : $Y = 1007 + 30.8X_1$
(6.65) p= .001
R^2= 38 Durbin Watsun Statistic = 1.8

Thus we may suggest the usefulness of a composite index based on less complicated observations, similar to those submitted here, for the assessment of equity and productivity of water.]

An adequate treatment ot the analysis of fertilizer use and its interaction with water availability during different stages of crop growth etc. is beyond the scope of this report. In addition this task calls for close observations at individual farm level,for instance, in regard to such factors as timing and quality of applications and soil type. Within M-31 itself we observe a significant variability in regard to these aspects. For instance, 18 percent of farmers had used ammonium sulphate, a kind of fertilizer which is not recommended. Average level of fertilizer use in shown below (refers to the amount of the mixture and not the nutrient Kg).

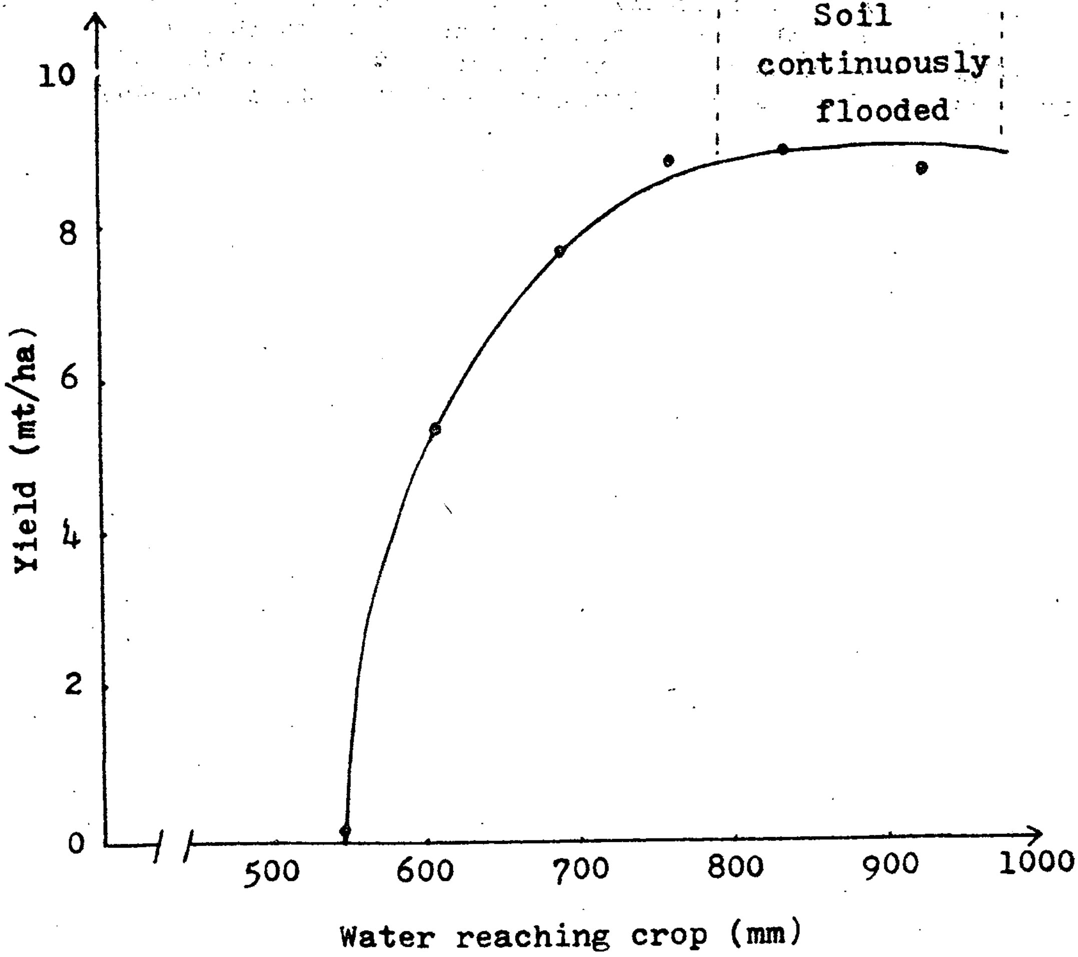
	Kg/ha	Std.Dev
Top dressing mixture	296	180
Urea	416	202
Amm.Sulphate	51	147
V_1 mixture	280	219

As mentioned at the outset, the main objectives of the present analysis was to : suggest indicators to assess the reliability and adequacy of water input, examine productivity and equity aspects of water distribution and compare main and terminal system in terms of water status, crop analysis beyond the scope of this analysis, one may have to conduct an indepth analysis at microlevel with a manageable size of sample appropriate to such an examination.[10]

89

Appendix A

Figure A.1. The yield of rice (IR_8) as a function of applied water Dry Season, 1969, Los Banos, Philippines (R.Reyes, Unpublished data, IRRI).



Source (4)

On the other hand, to assess the pattern water allocation and productivity at the macro level, one may have to extend the analysis to cover such aspects as trade offs between a) water allocation to sugar plantations and paddy b) the differences between the 'observed' (as measured at the tri-funcation below the main reservoir) and 'actual' (for instance diversions to river division through the Kotdawatawana tank and 'Left Bank Drainage') allocations of water to L.B., R.B. and R.D. In addition, an analyisis of distribution of net benefits among individuals in the entire Gal Oya system also becomes imperative in this regard.

---

[10] For instance, as we observed from he Tables in Section 4.2, higher yield levels do not necessarily lead to higher levels of profits. In addition to the high degree of variability observed in the use of variable inputs considered in this analysis (quantitative) there may be other factors that are responsible for these differences. Among them we may find differences in a) management, and b) quality of the factors of production, including soil type and topography.

TABLE A.1

Yield and WAI - Classified by Distributary and Field Channels - MAHA 1981/82

Subsystem	Yield Kg/Ha	W.A.I.	Subsystem	Yield	W.A.I.
Subsys 1			Subsys 2		
L.B.7	3360	182	D.R.	3645	178
FCH-0*	3343	177	L.B.14	3154	193
FCH-1	4511	193	FCH-1	2732	193
FCH-3	4124	188	FCH-2	3322	193
FCH-4	2005	180	L.B.19	3477	184
FCH-5	3763	178	FCH-0*	3634	187
FCH-6	3162	173	FCH-1	3512	184
FCH-7	3866	175	FCH-2	3409	183
L.B.10	3739	189	Subsys 4		
Subsys 3			M	3417	195
			M1		
D.R.	2987	175	FCH-0*	2474	194
U.B.2	3334	188	FCH-1	3162	195
FCH-0*	4072	191	FCH-2	3385	196
FCH-1	3385	192	FCH-3	2489	195
FCH-2	3190	188	FCH-4	3828	195
FCH-3	3064	187	FCH-5	4420	197
FCH-5	3235	184	M31	3265	174
FCH-9	3677	187	FCH-1	3806	180
U.B.17	2432	191	FCH-3	2408	167
			FCH-4	3419	--
			FCH-5	3262	169
			FCH-6	4249	191
			FCH-8	2620	172
Subsys 6			Subsys 7		
D.R.	3714	168	L.B.29	3069	194
G24	2705	-	L.B.39	2896	175
FCH-1	2627		FCH-0*	3119	176
FCH-2	2797		FCH-1	2378	175
FCH-3	2831		FCH-3	3080	174
Subsys			Subsys		
V2 .	2459	175	D.R.	3137	170
FCH-0*	2463	- 174	T10.	2107	159
FCH-1	2455	176	FCH-1.0	1817	
V21	1996		FCH-1.1	1366	
FCH-0*	2183		FCH1.2	2199	
FCH-2	2120		FCH-2.0	1456	
FCH-3	1648		FCH-2.3	1634	
			FCH-3.0	2637	
			FCH-3.1	1856	
			FCH-3.2	2346	
			FCH-3.4	1405	

---

* FCH-0 = Private and encroachments mostly under drainage.

TABLE A.2

Yield and WAI - Classified by Distributary and Field Channels - YALA 1982

Subsystem	Yield Kg/Ha	W.A.I.	Subsystem	Yield Kg/Ha	W.A.I.
Subsys 1			Subsys 2		
L.B.7	4063	178	D.R.	3368	--
FCH-0	3157	174	L.B.19	3732	--
FCH-1	4201	182	FCH-0	4317	
FCH-3	3840	171	FCH-1	3377	
FCH-4	4588	186	FCH-2	3273	
FCH-5	4678	178			
FCH-6	4917	187			
FCH-7	4459	180			
L.B.10	3174	187			
Subsys 3			Subsys 4		
U.B. 2	3472	188	M_1	3469	192
FCH-0	4098	190	FCH-0	3286	194
FCH-1	3600	192	FCH-1	2816	180
FCH-2	3570	189	FCH-2	3651	188
FCH-3	3214	188	FCH-3	3647	196
FCH-5	3467	190	FCH-4	3982	196
FCH-9	3815	187	FCH-5	3995	196
FCH-10	2926	184	M16	2204	170
U.B.14	3067	187			
FCH-1	2629	184	FCH-0	2191	167
FCH-2	3445	189	FCH-1	2199	178
U.B.17	2765	186	FCH-2	2211	168
Subsys 6					
G3	2658	175	Subsys 7		
FCH-0	4124		L.B.29	2711	181
FCH-1	1804		FCH-0	2324	179
FCH-2	2500		FCH-1	3056	185
FCH-3	2681		FCH-2	3928	186
FCH-4	2483		L.B.39	2425	178
FCH-5	2577		FCH-0	2350	176
FCH-6	2668		FCH-1	2532	179
			FCH-3	2428	178
			Subsys 9		
G16	3230	168	D.R.	3220	176
FCH-0	3650	170	S8		
FCH-1	2358	165	FCH-0	2938	180
FCH-2	--	161	FCH-1	2384	177
			FCH-2	2690	173
Subsys 8			Subsys 8 contd.		
V_2	2265	175	V_{12}	3320	189
FCH-0	2283	175	FCH-0	3272	189
FCH-1	2249	174	FCH-1	3331	190
			FCH-2	2990	193
			FCH-3	3489	188

TABLE A.3

Yield Classified by Subsystems, Distributary and Season

Subsystem and D-Channel	MAHA SEASON Yield		YALA SEASON Yield	
	Mean	Standard Deviation	Mean	Standard Deviation
Subsys. 1	3484	1383	3692	1220
L.B. 7	3360	1292	4063	1017
L.B. 10	3739	1574	3174	1324
Subsys. 2	3399	962	3498	593
D.R.*	3645	1128	3368	589
L.B. 14	3154	599	N.A.	N.A.
L.B. 19	3477	1094	3732	584
Subsys. 3	2980	882	3097	753
D.R.*	2987	874	N.A.	N.A.
U.B. 2	3334	677	3472	503
U.B. 14	N.A.	N.A.	3067	540
U.B. 17	2432	946	2765	897
Subsys. 4	3308	1700	2746	889
M 1	3417	1545	3469	816
M 16	N.A.	N.A.	2204	450
M 31	3265	951	N.A.	N.A.
Subsys. 6	3222	1059	2985	3117
D.R.*	3714	988	N.A.	N.A.
G 3	N.A.	N.A.	2658	516
G 16	N.A.	N.A.	3230	4128
G 24	2705	886	N.A.	N.A.
Subsys. 7	2870	871	2568	143
L.B. 29	3069	1032	2711	1057
L.B. 39	2896	761	2425	174
Subsys. 8	2150	575	3033	733
V 2	2459	386	2265	233
V 12	N.A.	N.A.	3320	642
V 21	1996	756	N.A.	N.A.
Subsys. 9	2382	761	2953	465
D.R.*	3137	523	3220	378
S 8	N.A.	N.A.	2815	461
T 10	2107	1180		

* D.R. = Drainage or Rainfed

TABLE A.4

WAI Classified by Subsystems, Distributary and Season

Subsystem and D-Channel	MAHA SEASON WAI Mean	MAHA SEASON WAI Standard Deviation	YALA SEASON WAI Mean	YALA SEASON WAI Standard Deviation
Subsys.1	186	8.4	182	16.0
L.B.7	182	8.2	178	19.0
L.B.10	189	8.5	187	6.2
Subsys.2	186	7.0	-	-
D.R.*	178	4.3		-
L.B.14	193	3.2		-
L.B.19	184	5.6		-
Subsys.3	183	17.0	187	5.7
D.R.	175	23.0		
U.B.2	188	3.7	188	3.8
U.B.14	-	-	187	3.9
U.B.17	191	7.8	186	12.0
Subsys.4	182	14.0	179	13.0
M1	195	3.5	192	8.0
M16	-	-	170	5.5
M31	174	15.0	-	-
Subsys.6	168	7.0	169	7.2
D.R.	168	7.0	-	-
G3	-	-	175	0.0
G16	-	-	168	7.3
Subsys.7	184	4.6	179	5.6
L.B.29	194	5.8	181	8.9
L.B.39	175	3.4	178	4.0
Subsys.8	175	2.7	185	6.9
V2	175	2.7	175	1.9
V12	-	-	189	2.8
Subsys.9	170	8.3	177	11.0
D.R.	170	8.3	176	15.0
S8	-	-	178	4.5
T10	159	7.2	-	-

* D.R. = Drainage or Rainfed.

LIST OF REFERENCES

1. ARTI. 1979. Water Management Project - A Proposal for Socio-economic Research in Water Management in Sri Lanka.

2. Barker, R.Consultancy Reports and Trip Reports on visits to Gal Oya, 1979 to date - mimeo.

3. __________. Yield and Fertilizer Input. In Changes in Rice Farming in Selected Areas of Asia, IRRI, 1978.

4. Bhuiyarn, Sadiquel, I. In Water Allocation, Distribution, and Use Criteria for Irrigation System Design and Management : Selected Research Findings, IRRI.

5. de Data, S.K. et al. 1973, Water Stress Effects in Flooded Tropical Rice, in IRRI, Water Management in Philippine Irrigation Systems: Research and Operations.

6. F.A.O. 1979. Irrigation and Drainage Paper No. 33, Article on Rice (Paddy), by J.Doorenbos et al.

7. Levine, Gilbert. 1979. Management Components in Irrigation System Design and Operation, In Agricultural Administration, Vol. 4, No.1, Jan. 1977.

8. Miranda, S.M. and G. Levine. 1976. Effects of Physical Water Control Parameters on Lowland Irrigation and Water Management, In Irrigation Policy and the Management of Irrigation Systems in Southeast Asia, ed. Taylor, D.C. and T.H. Wickham.

9. Murray-Rust, D.H. 1983. Irrigation Water Management in Sri Lanka: An Evaluation of Technical and Policy Factors Affecting Operation of a Main Channel System, Doctoral dissertation, Department of Agricultural Engineering, Cornell University.

10. Reyes, R.D, and T, Wichkam, 1973. The Effect of Moisture on Stress and Nitrogen Management at Different Growth States on Lowland Rice Fields. Paper presented at the 4th Scientific Meeting of the Crop Science Society of the Philippines, 21-23 May 1974, Cebu.

11. Small, L. and C. Capule. 1981. An Index to Evaluate the Effect of Water Shortage on the Yield of Wetland Rice, IRPS No. 70, December 1981, IRRI.

12. Svendsn and Wijayaratna. The Spatial Distribution of Irrigation Water and Yields on the Gal Oya Left Bank. Sri Lanka Journal of Agrarian Studies 3(2), 1982, 69-82.

13. Tabbal, D.F. and T.H. Wickham. Effects of Location and Water Supply on Water Shortages in an Irrigation Area. In Irrigation Policy and the Management of Irrigation Systems in Southeast Asia (1979) ed. Taylor, D.C. and T.H. Wickham.

14. Valera, A.D., D. Tabbal, R. Reyes and R. Barker. 1970. The Effect of Improved Water Control in Irrigation Canals on Crop Production, In Irrigation Policy and the Management of Irrigation Systems in Southeast Asia (1979) ed. Taylor, C.C. and T.H. Wickham.

15. Wickham, T.H. 1971. Water Management in the Humid Tropics: a Farm Level Analysis. Unpublished Ph.D. Dissertation, Dept. of Agricultural Engineering, Cornell University.

16. Wijayaratna, C.M. et al. ec. 1982. 1980 Yearbook for Sri Lanka. Water Management Research.

17. Wijayaratna, C.M. 1982. Spatial Pattern of Water Adequacy and Resulting Farmer Responses in a Tank Irrigation Scheme of Sri Lanka. Paper presented to workshop on Modernization of Tank Irrigation: Problems and Issues, Peratigna Anna University of Technology, Madras.

18. __________. 1982. Uneven Distribution of Water: Causes, Consequences and Implications for System Management. Paper presented to the workshop on water Management in Sri Lanka, January 1982.

19. __________. Confronting Tight Water Supply Conditions: Lessons from Jointly Managed Systems. A paper presented to International Workshop on "Contingency Irrigation Planning for Command Area during deficit rainfall year." August 1983: Dept. of Agricultural Engineering, College of Agriculture, Regendranagas, Hyderabad.