STATUS RESEARCH REPORT: SRI LANKA

C.R. Panabokke* and the IIMI Crop Diversification Group[1]

INTRODUCTION

With Sri Lanka rapidly approaching self-sufficiency in rice production, the government's recently published National Agriculture, Food and Nutrition Strategy (1984) recognizes the imperatives for a major policy shift in the present utilization of the country's irrigated land resources.

The major irrigation systems located in the dry zone have provided the basis for the increases in rice production recorded in the recent decade. These systems are where most of the scope lies for avoiding over-production of rice in the future. Of the 740,000 hectares (ha) available in Sri Lanka for rice, the major irrigation systems presently account for a little over 250,000 ha. A further 60,000 ha of new irrigated land will probably be developed under the Mahaweli program during the next decade.

Prior to the mid-1960s, the major reservoir irrigation systems were essentially designed to provide water for a single crop of rice during the wet _maha_ season; any water that was saved in the reservoir at season's end was used to grow a limited area of rice during the following dry _yala_ season.

Since the late-1960s efforts were made by the different agencies under the Ministries of Agriculture and Irrigation to promote non-rice crops in several major reservoir irrigation systems during the yala season when water supplies were restricted. The main thrust of the approach promoted diversified crops on irrigated land with intensive extension service support that emphasized timely supply and distribution of irrigation water and improved organization of credit and input supply. Because of the lack of a clear understanding of the constraints to diversified cropping as well as an inadequate knowledge of managing the irrigation system for dry season non-rice cropping, this approach had only limited success. Furthermore, in several cases farmers produced non-rice crops with highly variable results, reasons for the success or failure were not well understood either by the extension services or by the farmers themselves.

Subsequent research and pilot testing studies undertaken in the early and mid-1970s by the Department of Agriculture and the Mahaweli Agency led to the development of appropriate on-farm agronomic and water management recommendations (Somasiri 1981). The new design and layout of the distribution system in the Mahaweli H System assumed that farmer/settlers would readily adopt these management practices. But, although farmer/settlers responded to the attractive price incentives for chilli and soybean, important deficiencies were observed in the productive use of land and irrigation resources.

Underlying this study is the assumption that more productive use of existing irrigation infrastructure and associated land resources can be

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*Agronomist, International Irrigation Management Institute, Sri Lanka.

accomplished by intensifying diversified cropping systems and through more effective irrigation system management. The studies revealed that there are important technical and socio-economic aspects to irrigation management for diversified cropping which are not yet clearly understood and which have an important bearing on the profitability of cultivation and the return to investment in irrigation. It also points to the need to properly identify the constraints to successful diversified cropping in irrigated areas and to explore ways to relax these constraints.

RESEARCH OBJECTIVES

Crop Diversification

The crop diversification component hopes to identify and develop strategies to facilitate more intensive diversified cropping in areas that have been primarily developed for producing flood irrigated rice. The specific objectives are to:

1. identify existing and potential irrigation practices for non-rice crops at the main system, tertiary system, and farm field levels;

2. identify incentives for and constraints to the further expansion of non-rice crops;

3. identify and pilot-test possible improvements in irrigation management to facilitate the growing of non-rice crops in areas where soil conditions, topography, crop profitability, and other factors generally favor non-rice crops; and

4. make recommendations concerning the adoption of improved irrigation practices in irrigated non-rice crop production, based on an assessment of the impacts on irrigation and crop production performance of the pilot-tested irrigation practices.

Irrigation System Management

The broad objectives of this component are to establish measures for the operational efficiency of the identified irrigation systems; identify any performance deficiencies and assess their relationship to management; and develop, test and recommend management interventions designed to improve systems management. The specific objectives are to:

1. assess the adequacy of water deliveries at various levels, including the farm field level, from the perspectives of both the water suppliers and water users;

2. identify underlying principles of irrigation management (e.g., procedures for decisions on the timing and amounts of water allocated at various levels within an irrigation system-both before the irrigation season begins and during the season when unexpected water shortages may occur;

3. identify the nature of Operations and Maintenance (O&M) activities by the main system management, tertiary system management, and individual irrigators, and the nature of institutional relationships among them;

4. based on the above objectives, identify and pilot-test possible improvements in irrigation management to facilitate irrigated crops; and,

5. make recommendations concerning the adoption of improved irrigation practices in crop production based on an assessment of the impact on irrigation and crop production performance of the pilot-tested practices.

METHODOLOGY

Selection of Field Research Sites

The following factors were considered: a) the type of administration of the system, b) nature of water source, and c) size and age of project. These factors were considered because they cut across a wider range of irrigation systems found in this country than factors such as design, layout, and manner of regulation.

Type of administration. Each irrigation system under the Mahaweli Agency is headed by a Resident Project Manager. The System is subdivided into Block Areas, each under a Block Manager. These are subdivided into Unit Areas each made up of 250 settler families under a Unit Manager.

Each irrigation system under the Irrigation Department is administered by a resident Irrigation Engineer and supported by Technical Assistants. A recent innovation introduced by the newly created Irrigation Management Division (IMD) is the appointment of a Project Manager on major schemes to coordinate all services of line agencies.

Nature of water source. The Mahaweli system represents large local irrigation reservoirs linked to a substantial outside diversion source of water. In contrast, the major irrigation systems under the Irrigation Department have an independent local storage reservoir within its own catchment.

Size and age of project. The Dewahuwa system consists of a reservoir with a capacity of 12 million cubic meters (MCM; 9,898 acre feet) and a channel network commanding a total area of 1,215 ha. The command area is divided into nine irrigation tracts (Figure 1). The main canal is 16 kilometers (km) long and has a design capacity of 2.72 cumecs (96 cusecs) at the head. The transit time for water to reach the tail end of the canal in the filling phase at the beginning of a rotation is around 12 hours. The individual farm allotments of 2 ha each are served via a network of distributary and field canals. Source of supply to farm allotments is from field channel outlets as well as direct outlets either from the main canal or distributary. The issue tree diagram for this system is shown in Figure 2 and field research site features are listed in Table 1.

Figure 1. Schematic of Dewahuwa Irrigation System, Sri Lanka.

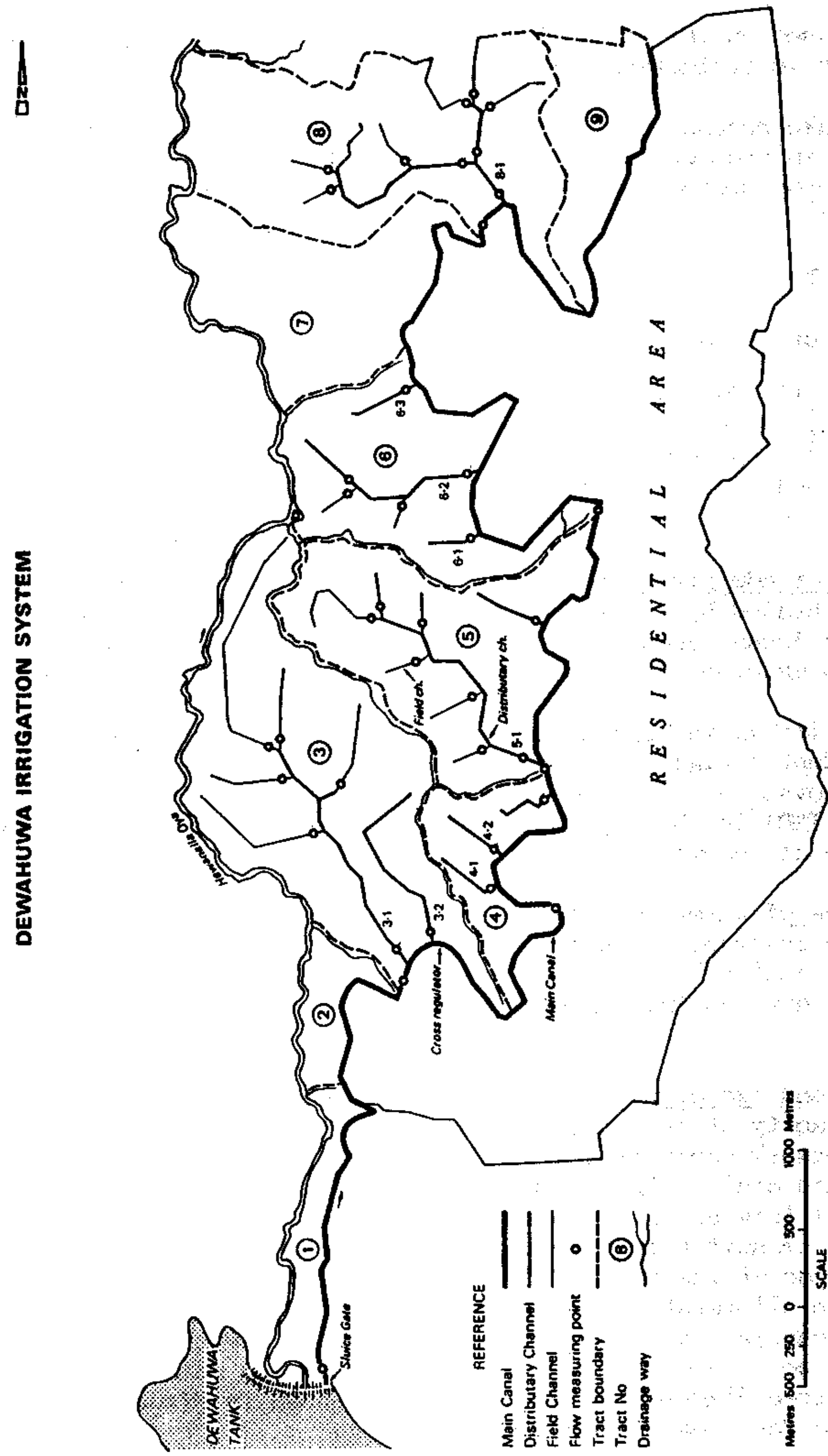
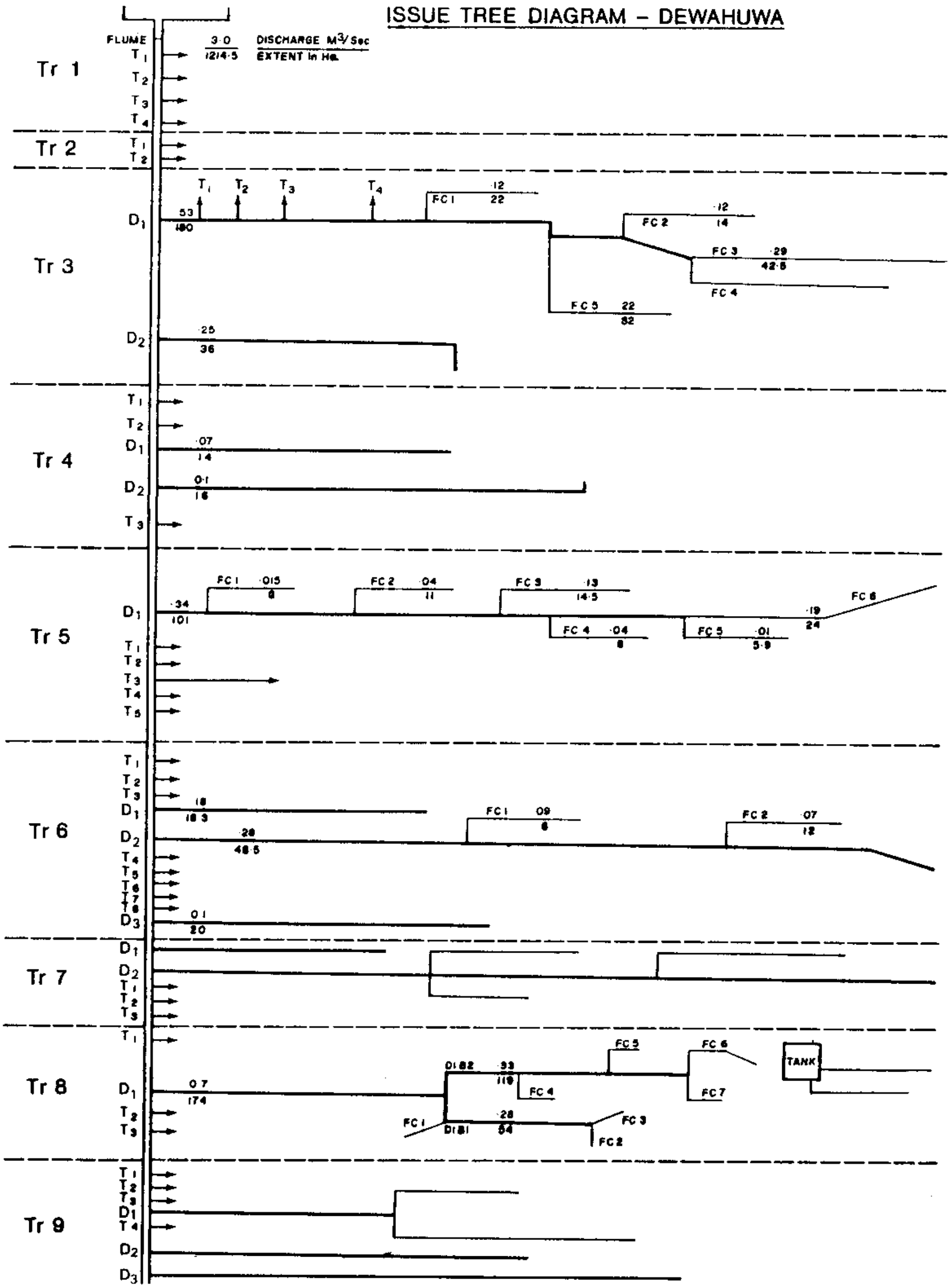


Figure 2. Issue tree diagram of Dewahuwa Irrigation System, Sri Lanka.



Under a Japanese funded project in the early 1970s, the main canal was desilted, slopes were stabilized, regulating and measurement structures were installed in the main canal, and steel gates and rectangular sharp-crested weirs were installed at the heads of the distributary canals. Most of the canal regulators are in poor condition at present and their gates are either missing or damaged. Similarly, turnout gates, especially in direct turnouts from the main canal and distributaries, are in poor condition.

Table 1. Field research site features, Dewahuwa and Kalankuttiya Irrigation Systems

	Dewahuwa	Kalankuttiya
Type of administration:	Irrigation Dept	Mahaweli Authority
Nature of water source:	Own catchment and occasional diversion from Nalanda Oya Reservoir	Diversion from major river storage system and local storage
Size:	Total command - 1215 ha Irrigation Tracts 1-9 Partial Rehabilitation in 1973	System H - 24,240 ha Kalankuttiya Block in H2 - 2,121 ha
Settlement commenced:	1949	1977

The Kalankuttiya system consists of the Kalankuttiya tank which has a capacity of 1.86 MCM (1,534 acre feet) and which receives supplies from the main Mahaweli system. The water distribution system (Figure 3) consists of a branch canal 11 km long and 20 distributary channels serving a command area of 2,040 ha. The branch canal has a maximum design capacity of 5.65 cumecs (200 cusecs) at the head end area. The distribution system provides irrigation to 5 Irrigation Blocks, numbers 305-309, within the whole of the Kalankuttiya Administrative Block. Duckbill weir cross regulators help to maintain the desired hydraulic head at different sections of the canal thereby ensuring a controlled discharge to the distributaries. The issue tree diagram for this system is shown in Figure 4.

All distributary channel outlets have a measuring weir immediately below the gate. The field channels that take off from the distributary channel have had turnout gates; in some turnouts the gates have been either removed or damaged by farmers. Most of the monitoring devices such as calibrated staff gauges and weirs installed below turnouts have been damaged or removed by farmers, and the control of flow to the field channel has to be done by eye estimation or via past experience. Supply to field allotments of one hectare each is from field channel outlets. Within a field channel it is difficult to find any original outlets in good condition.

Figure 3. Schematic of Kalankuttiya Block of Mahaweli System H, Sri Lanka.

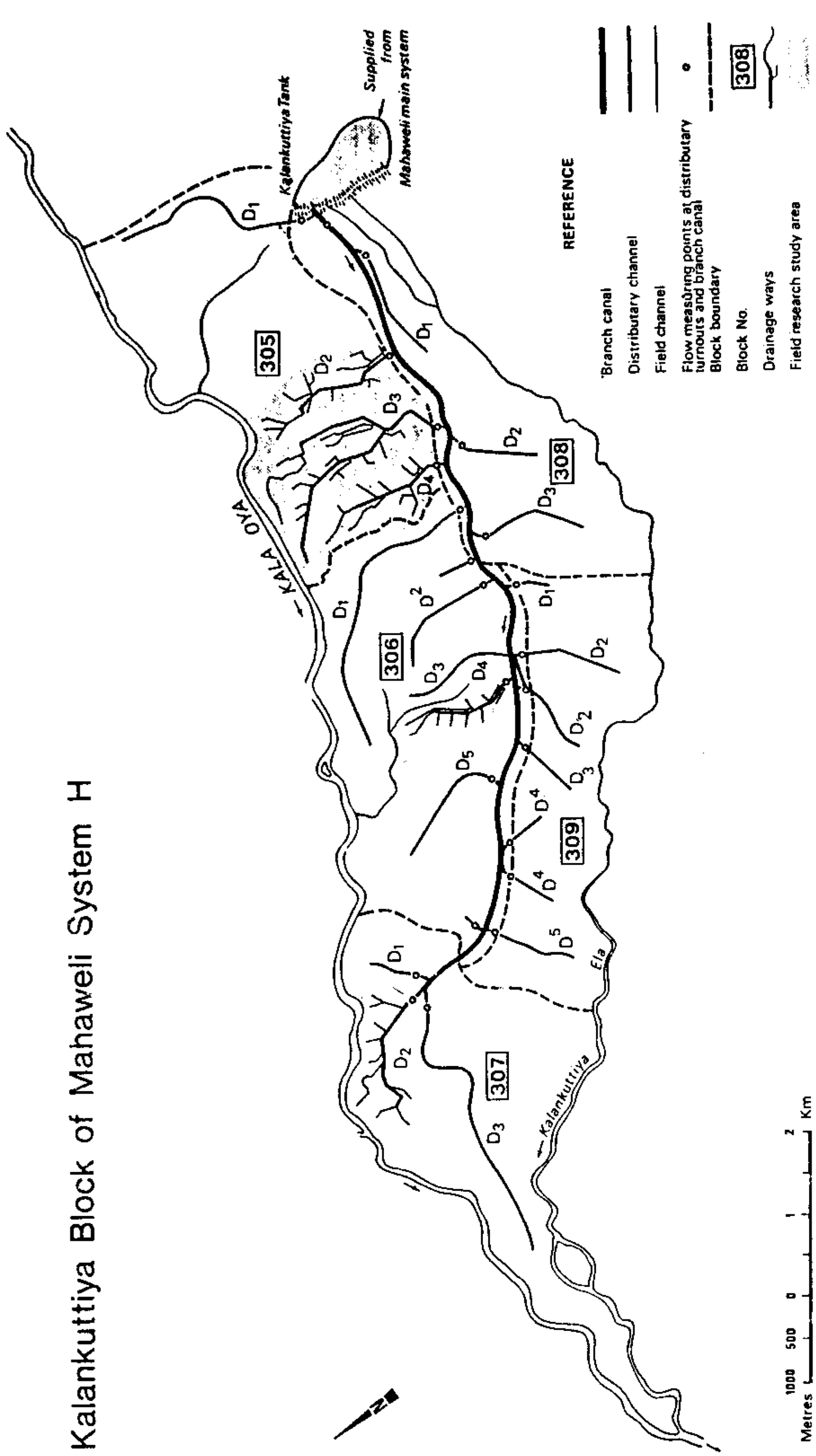
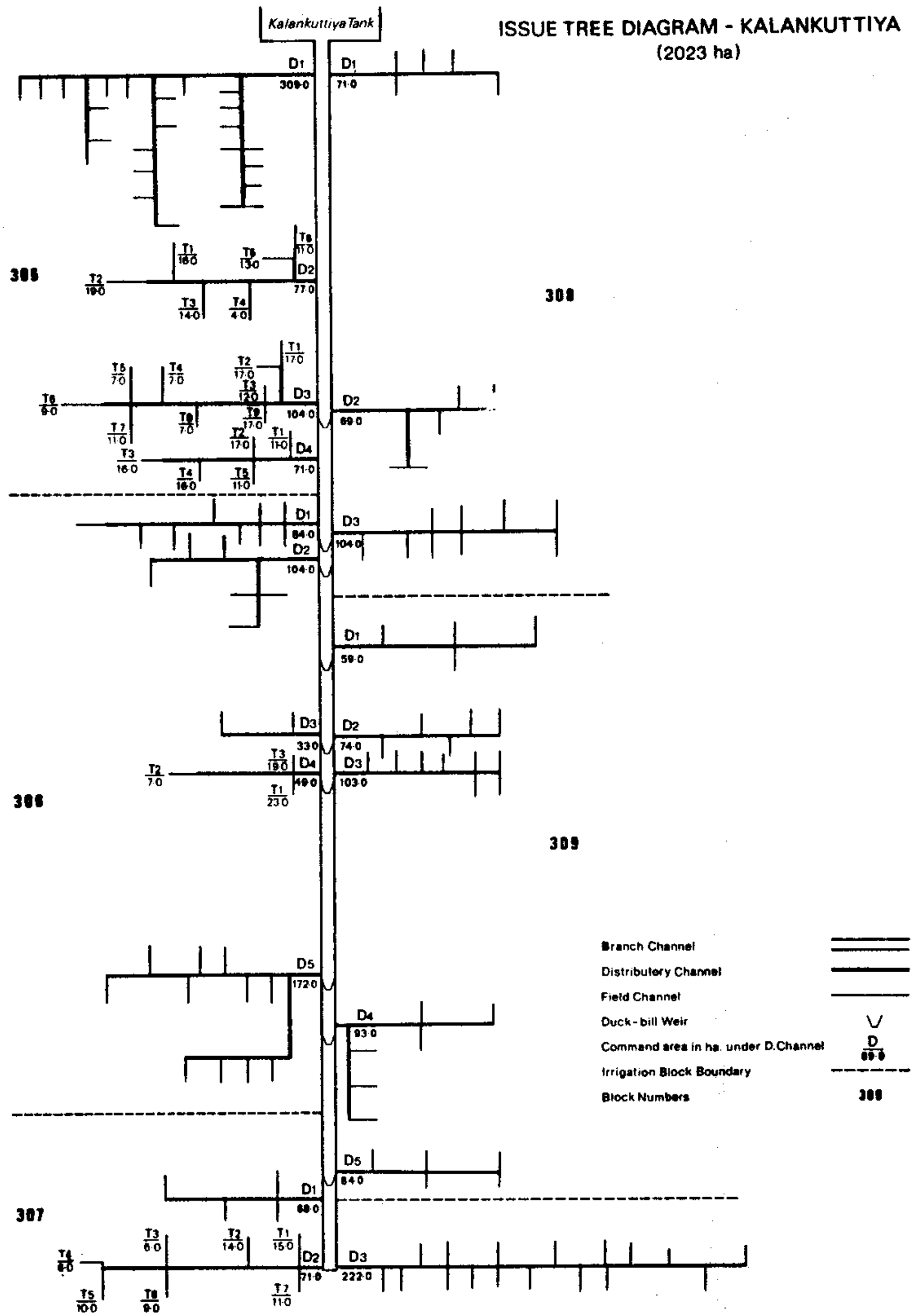


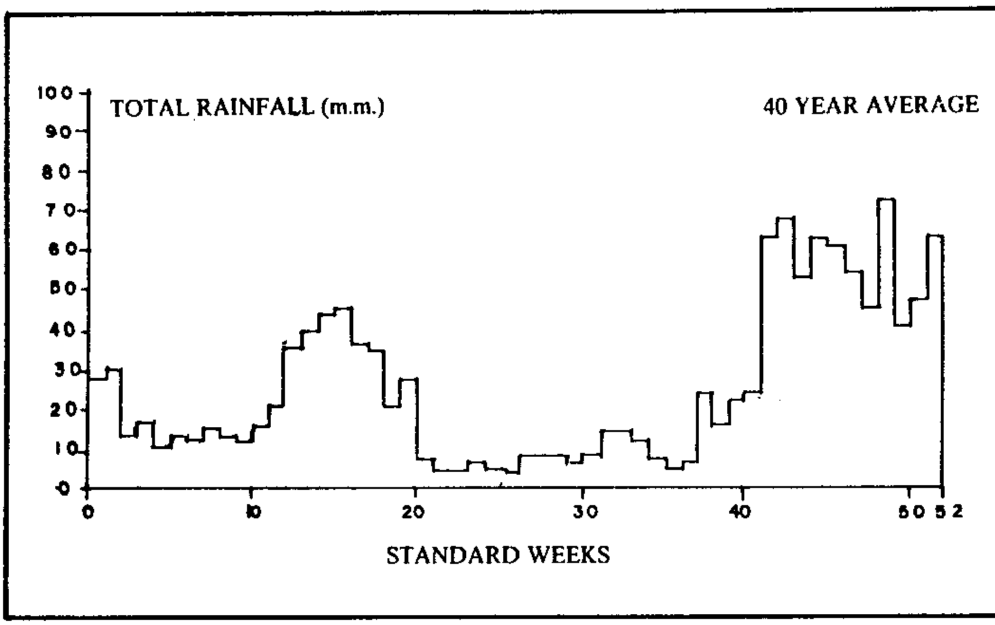
Figure 4. Issue tree diagram for Kalankuttiya Block of Mahaweli System H, Sri Lanka.



Climate and Soils

This region is characterized by a bimodal distribution pattern for the monthly rainfall with two distinct dry periods, one short and other prolonged (Figure 5).

Figure 5. Total annual rainfall distribution (in millimeters).



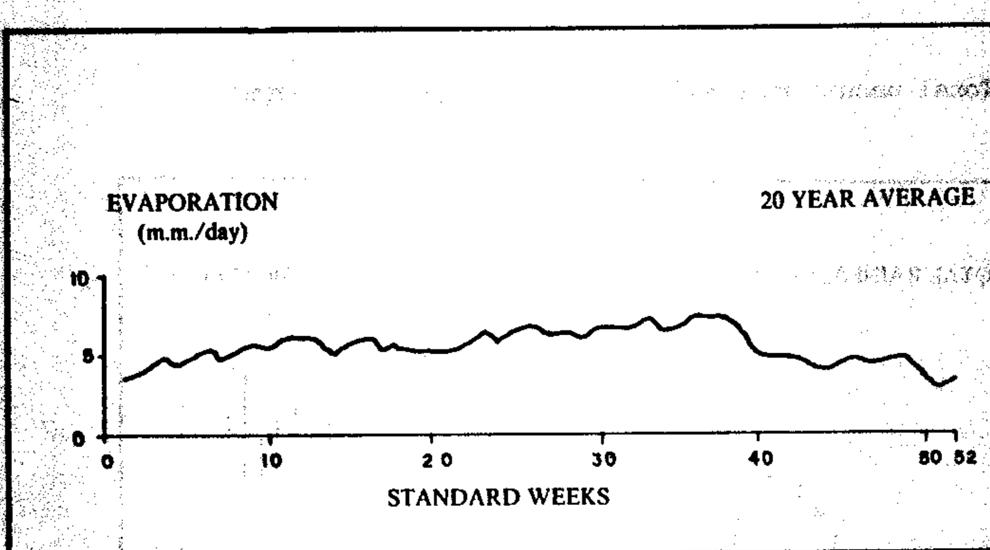
The annual average rainfall is 1,500 millimeters (mm), of which nearly 70 per cent occurs from October to mid-January, the maha season. The remaining rainfall occurs from mid-March to mid May, the yala season. February, June, July, August, and September are relatively rainless. The 75 per cent probability of rainfall expectancy in the maha season is 430 mm and 200 mm in the yala season.

The pan evaporation measured from a class A pan varies from 3.5 mm/day - 7.5 mm/day (Figure 6). From the 1st week of October to the end of January, the pan evaporation is less than 5 mm/day. The pan evaporation from June to the end of September is over 6 mm/day (Figure 6).

The annual average temperature is 26°C. The minimum temperature varies between 20°C and 25°C over the year; while the maximum temperature varies between 27°C and 34°C. The daily temperature fluctuation over 10°C occurs during the period mid February to end of April.

The solar radiation is quite low during the maha season. This is mostly due to the cloud cover. The lowest value of the solar radiation is 300 calories/day which occurs during December.

Figure 6. Class A pan evaporation (in millimeters/day).



The soils in the irrigation command areas occur in a catenary sequence in the undulating landscape. The well-drained and imperfectly drained Reddish Brown Earths (RBE) are found in the convex uplands and mid-slopes respectively. Poorly drained Low Humic Gley (LHG) soils occur in the concave valleys and bottom-lands.

In the past the LHG soils were utilized for continuous cultivation of rice both under rainfed and irrigated conditions. With the development of new irrigation schemes, all the soils in the catena were brought under cultivation. Rice was the only crop grown in these lands in the beginning. However, loss of excessive quantities of water was observed due to the high seepage and percolation rates in the well-drained and imperfectly drained lands when standing water was maintained for rice. Other field crops (OFC)* were therefore introduced to overcome the situation. Consideration of ground water-table behavior and drainage became increasingly important since other field crops proved to be intolerant of excess moisture conditions.

Research Procedures

The main part of the research activity was field observation, including data collection and analysis for the first three research objectives under crop diversification and irrigation systems management. Flow discharge measurements and detailed farm survey data were collected at each site. The following summarize the variables on system management and flow discharge measurements that were included in the study:

1. Decisions reached in cultivators' meetings before each season:
   a) Scheduled first water issues
   b) Planned areas by distributary or tracts to be served with water and for what crops
   c) Schedules of water delivery

2. Actual water delivery:
   a) First water issue
   b) Areas actually planted and served with water under each distributary or tract
   c) Actual dates of water deliveries
   d) Who gives instructions and who actually does the following:
      i) Opening and closing of main sluice?
      ii) Adjusting cross regulator settings?
      iii) Opening and closing of gates to distributaries?
      iv) Opening and closing of turnouts to field channels?
      v) Opening and closing of field outlets?

   e) How is water shared below the field channel turnout and below the field outlet?
   f) How is water applied to the individual basins for diversified crops?

3. Interval, duration, and flow rate of irrigation issues from:
   a) Main canal
   b) Distributary canal
   c) Field channel
   d) Field outlet

Data was collected for the following variables at each site in respect of the Farm Survey:

1. General farm characteristics
2. Cropping patterns
3. Cropping activities
   a) Land preparation
   b) Crop establishment

4. Crop care:
   a) Application of fertilizer - amount, kinds, and cost
   b) Pesticides and herbicides - amount, cost

5. Labor use for all operations - family, hired, and exchange
6. Harvesting - dates, and costs including threshing and transport
7. Production - yields by taking crop cuttings
8. Crop utilization - consumption, marketing, and seed requirements
9. Marketing - private trade, government agencies, prices
10. Credit - banks and private money lenders

Information on other forms of highland rainfed cultivation, and ex-farm employment activities were also documented.

SYSTEM MANAGEMENT

Planning

Dewahuwa. In planning for the season, a Technical Assistant from the Irrigation Department used past available data to determine the area that could be irrigated, crops to be planted, and timing of rotations. The proposals were presented to farmers at the pre-kanna or pre-season meeting.

For yala 1985, agreement was reached to cultivate one third the total command area under a bethma or land sharing basis. Crops were to be chilli, soybean, and green gram on the well-drained soils, and rice on the poorly-drained soils. A 15 day continuous supply of water was to be given for land preparation followed by rotational issue every ten days. For maha 1985 in keeping with the normal practice, it was agreed to cultivate the whole command area with rice. Yala 1986 was handled like yala 1985 except that it was agreed to cultivate half the total command area rather than one third.

Kalankuttiya. For yala 1985, officials of the Kalankuttiya Block office explained to farmers that water was inadequate for a full cultivation of the total area of 2,122 ha. Agreement was reached that a bethma cultivation would be done on half the command area of each distributary. Chilli would be planted on the well-drained soils, and rice on the poorly-drained soils. A 30 day continuous supply of water would be given for land preparation followed by a rotational issue every seven days. For maha 1985, in keeping with the normal practice, it was agreed that the whole command area would be grown to rice. For yala 1986, a bethma was not necessary because the area was provided its full quota of water, and it was agreed that the whole command area under every distributary would be cultivated with chilli on well-drained and rice on the poorly-drained soils.

Results and Discussion: Dewahuwa

Yala 1985. One-third of the total command area, 477 ha from different areas within tracts 1-6, was cultivated. Rice occupied 61 ha and other food crops (OFC), 416 ha. Irrigation issues for land preparation were planned for 15 days but accomplished in 8 days using 174 mm of water. As seen in Table 2, the weighted mean values of delivery for the distributaries in tracts 4-6 amount to 183, 151, and 119 mm, respectively. With 13 per cent of the total irrigated area used for rice, land preparation was mainly for OFC which requires less water than rice for the land preparation methods adopted. Eleven rotational issues of water totalling 881 mm were given over a 128-day crop growth period. The weighted mean value for distributaries in tract 4 is 940 mm compared with 485 mm in tract 6.

When only one-third of the area (477 ha located in the head reaches) was cultivated, about 1.52 cumecs (54 cusecs) was issued in the main canal after land preparation with 3 days on and 7 days off. The issues in the distributaries followed the same schedule. However, in the field channels, it was 1.5 days on and 8.5 days off, with the upper half of the turnouts located along distributaries receiving the water first and then the lower half. All the field outlets along the field channels received water simultaneously.

Table 2. Variables involved in land preparation (LP) and crop growth (CG) for three seasons, Dewahuwa, 1985-86.

	Yala 1985		Maha 1985-86		Yala 1986	
	LP	CG	LP	CG	LP	CG
No. of days	8	126	30	123	15	114
Rainfall (mm)	6	145	83	774	34	54
Evaporation (mm)	35	558	78	240	54	497
No. of rotational issues	-	11	-	14	-	13
Total area (ha)	477	-	1214	-	607	-
OFC (ha)	-	416	-	-	-	481
Rice (ha)	-	61	-	1214	-	126
Irrigation Supply (mm):						
Main channel	174	881	536	1174	121	850
Tract 3: Distributary	-	-	746	1233	172	1056
Turnout	-	-	586	1360	132	886
Tract 4: Distributary	183	940	529	883	144	1500
Tract 5: Distributary	151	558	703	1311	123	861
Turnout	155	473	418	817	95	545
Tract 6: Distributary	119	485	726	1105	147	630
Turnout	-	-	589	712	52	339

Maha 1985-86. The whole command area of 1,214 ha was cultivated in wet land rice. Water issues for land preparation were planned for 37 days and accomplished in 30 days using 536 mm. A continuous issue was given during the land preparation period for tracts 1-7. A two-day rotation was given to tracts 8 and 9, during this period because an adequate volume of flow could not be delivered to the tail end of the main canal. The mean delivery values for the distributaries in tracts 3, 5, and 6 exceed 700 mm (Table 2); this is probably due to the run-off water picked up by the single bank main canal (rainfall during this period amounted to 83 mm).

Fourteen rotational issues totalling 1,174 mm were given over a 123-day crop growth period. Flow in the main canal was about 2.74 cumecs (97 cusecs) and was on 4 days and off 3 days during each rotation. Tracts 1, 2, and 7, and parts of tracts 3, 5, 8, and 9 (Figure 1), received water on the first two days and the remainder received water on the second two days. For tracts with long distributaries, both upper and lower halves received water for one day each. The distributaries in tracts 3, 5, and 6 received similar amounts.

Yala 1986. Half the total command area (Figure 1), 607 ha which is located within tracts 1-6 and 10 allotments in tract 7, was irrigated this season with rice occupying 126 ha and OFC, 481 ha. Water issue for land preparation was planned for and accomplished in 15 days using 121 mm. Compared to the previous yala, 20 per cent of the total irrigated area was used for rice. The mean delivery values for distributaries in tracts 3-6 exceeds 121 mm, the value at main canal level (Table 2). While the mean value for distributaries is close to the value of the previous yala season, the mean value for the turnout in Tract 5 is considerably less.

Thirteen rotational issues totalling 850 mm of water were given over a 114-day crop growth period. Although a one-in-ten day rotation was planned, the management had to change to either a one-in-eight or a one-in seven-day rotation from the sixth rotation onwards to cope with the higher demand created by the greater area cultivated. Flow in the main canal was about 2.06 cumecs (73 cusecs) with the flow on for 3 days and off for 4 days during each rotation. The field channels were on for 1.5 days and off for 5.5 days. The long distributaries in both upper and lower halves received supplies for 1.5 days each. The mean delivery values for distributaries and turnouts in the head end tracts 3 and 4 are higher than in the tail end tracts 5 and 6.

On the longer distributary channels (i.e., Tract 5, D1) there is considerable conflict between head end and tail end farmers in sharing water. Monitoring turnouts revealed that tail end farmers had to rely on drawing irrigation supplies mostly during night, and very often had to cope with a larger stream size than they needed. This distributary has used a higher quantity of irrigation water in yala 1986 compared to that in yala 1985.

Discussion. The Dewahuwa irrigation system was originally designed to grow a single crop of rice during the wet maha season. System rehabilitation in the early 1970s with Japanese assistance improved the operational capacity of the system by installing regulating and measurement structures in the main canal, and measuring weirs at heads of distributary channels. Results from the flow measurements made during the last three seasons (two dry and one wet) confirm the feasibility of effectively managing this system for growing non-rice crops during the dry season by rotating water issues.

OFC cultivation using limited supplies of irrigation water has been promoted since 1984 under the sponsorship of the Agriculture, Irrigation, and Land Commissioner's Departments, and more recently the Irrigation Management Division (IMD) of the Ministry of Lands and Land Development. The present management has a good understanding of main system management and is capable of responding to the differential demands within the different sections of the system. However, more effective use of the existing cross regulating and measuring structures, and the provision of additional ones, could help to bring about substantial improvements in the main system management. A modest investment in repairs to regulating structures on the distributary channels will facilitate improved management, minimizing the present variation in supplies at the turnout level. Improved communication between farmers and agency staff is equally essential for improving management at the turnout.

Reported yields by crop cuts on sample allotments show good average yields for OFC during yala and for rice during maha, which generally indicate adequate water supplies. This is further confirmed by the absence of moisture stress for OFC. An important problem is the proper sharing of water between OFC and rice during yala. The supply within the present rotational issue pattern is advantageous for OFC but disadvantageous for rice.

Results and Discussion: Kalankuttiya

Yala 1985. Half the command area (1,100 ha) was cultivated; rice and OFC were both planted on 550 ha each. Irrigation issues for land preparation were planned for 30 days and accomplished in 36 days using 524 mm (Table 3). About 112 mm of rain fell during this period. Thirteen rotational issues totalling 1,002 mm of water were given over a 114-day crop growth period. During each rotation the branch canal and distributaries were open for four days and closed for three. The maximum branch canal issue was about 2.83 cumecs (100 cusecs). At the field channel level each field allotment drew its supply for 6-8 hours, allowing 16 allotments within a turnout area to be irrigated over 4 days (a 1 in 7 day delivery to each allotment). The total delivery for each distributary followed the same order as that during land preparation. The mean values for delivery at turnouts within a distributary ranged from 80-90 per cent of that delivered at the head.

Table 3. Variables involved in land preparation (LP) and crop growth (CG) for three seasons, Kalankuttiya, 1985-86.

	Yala 1985		Maha 1985-86		Yala 1985	
	LP	CG	LP	CG	LP	CG
No. of days	36	114	46	90	63	98
Rainfall (mm)	112	117	490	294	376	10
Evaporation (mm)	174	704	48	213	197	525
No. of rotational issues	-	13	-	10	-	12
Total area (ha)	1100	-	2040	-	2034	-
OFC (ha)	-	550	-	-	-	1040
Rice (ha)	-	550	-	2040	-	994
Irrigation Supply (mm):						
Main channel	524	1002	526	703	520	947
305, D2: Distributary	598	1006	623	728	550	929
Turnout	570	805	559	620	508	824
305, D3: Distributary	380	771	379	656	440	820
Turnout	372	676	358	508	440	633
305, D4: Distributary	418	880	455	513	439	766
Turnout	448	795	396	448	417	669
306, D4: Distributary	-	-	618	748	452	999
Turnout	-	-	405	422	430	946
307, D2: Distributary	-	-	634	797	592	1022
Turnout	-	-	506	612	481	821

Maha 1985-86. The entire command area of 2040 ha was cultivated to wet land rice. Irrigation issues for land preparation was planned for 30 days but was accomplished in 46 days using 526 mm of water. About 490 mm of rain fell during this period. The lengthier period for land preparation was not due to a constraint in water supply, but to a poor response by farmers to the management schedules. The flow measurement data in Table 3 shows that, as in the previous season, the amount delivered to the turnouts in the distributary D3 of Block 305 is less than for all other distributaries.

Ten rotational issues of water totalling 703 mm were given over a 90-day period for crop growth. The sluice was opened continuously with a maximum issue of 4.53 cumecs (160 cusecs); the first 15 distributaries were on for 4 days and off for 3 days. The last five distributaries received water from the fourth to the seventh day. The field channels were served with the same pattern of water issue as the distributaries. The mean values of delivery for field channels within a distributary range from 70-80 per cent of the values of the distributary except in 306 D4, which is closer to 60 percent.

Yala 1986. The entire command area was cultivated; rice was planned on 994 ha and OFC on 1,040 ha. Water issues for land preparation were planned for 30 days but took 63 days and used 520 mm. About 376 mm of rain fell during this period. The lengthy land preparation was again due to farmers not keeping to the scheduled operation plan. The farmers and the agency agreed to begin land preparation one month earlier than yala 1985, mainly to start an early chilli crop. But a delayed harvest of the preceding maha rice crop and the intervention of the Sinhala New Year holiday in mid-April caused a disruption to the proposed plan. Mean values of delivery for turnouts within a distributary are slightly more than 90 per cent of the amount delivered at the head of the distributary except in 307 D2 (Table 3).

Twelve rotational issues of water totalling 947 mm were given over a 98-day crop growth period. The rotational interval of issues to the branch canal varied from 7-12 days (6-7 days on and 1-5 days off) with a maximum issue of 5.09 cumecs (180 cusecs). The total delivery for each distributary follows the same order as in the land preparation period. When compared with yala 1985, a greater degree of variation in the total delivery between turnouts within a distributary occurred during yala 1986. These variations in values of delivery between turnouts within a distributary can be ascribed partly to the ratio of rice to OFC under its command, the position of the turnout either at the head or tail end of the distributary, and to the nature of operations conducted within it.

Discussion. The Kalankuttiya subsystem of the Mahaweli H system was designed for wet land rice during maha; and for OFC on well-drained soils and rice on the imperfectly- and poorly-drained soils during yala. The design and layout of the irrigation network makes a high degree of control and regulation possible up to turnouts leading to field channels. Branch canals, especially, have good regulation from duckbill weirs below each distributary gate. This enables self-management within the branch canal and equitable deliveries to its 20 distributaries. Flow measurement data confirm that this part of the main system can operate efficiently.

Flow measurement data also indicate that control and delivery within the distributary command can also operate satisfactorily. One problem is delivering adequate water to rice during yala within the weekly rotational issues. Rice yields under the present delivery pattern are about 2,500 kg/ha, which barely cover production costs. A shift away from rice at least on the imperfectly-drained soils has already been demonstrated by farmers who raise good crops of OFC, mainly chilli, by ridging and providing rudimentary drainage. This won't be possible on poorly-drained soils which, in any case, are benefitted by substantial seepage and can thus support a good rice crop. Confining rice to poorly-drained soils and promoting OFC on imperfectly-drained soils during yala would be an appropriate strategy that could be tested.

Managing deliveries below the field channel outlet is also a problem. Studies during yala 1986 show that both formal and informal arrangements exist among farmers for sharing water on a rotational basis. Although the original design called for two farmers to share the field channel issue for 12 hours, staff observed that of one farmer took the full flow for 6 hours. As a result, the outlet did not have adequate capacity to accommodate the full flow, encouraging farmers to either bypass or destroy the outlet. The conveyance system at this level is usually in poor shape and maintenance standards are low. Improving the management of water deliveries will therefore require both physical improvements to the conveyance system and closer participation between the managing agency and farmer representatives.

ECONOMICS OF DIVERSIFIED CROPPING UNDER IRRIGATION

To assess the agro-economic constraints to diversified cropping, data on both rice and other field crops (OFC) were collected at Dewahuwa and Kalankuttiya during yala 1985 and 1986. The purpose was to analyze the costs and returns of producing different crops. Some analysis was also made of the reasons for farmers' choice of crops. The managers of both systems promoted the cultivation of OFC during kanna meetings and by scheduling water issues, but many farmers in both systems also grew rice. In Dewahuwa, a significant amount of green gram and soybean were cultivated along with rice and chilli. In Kalankuttiya, chilli was the primary crop grown in addition to rice (other OFC accounted for about 4 per cent of the total irrigated area; Table 4).

Table 4. Crop area and sample size at Dewahuwa and Kalankuttiya, 1985-86.

	Sample farmers		Area Cultivated	
	Number	Per cent	Hectares	Per cent
		Dewahuwa, Yala 1985		
Rice	37	37	13.7	26
Chilli	41	41	19.3	36
Green gram	42	42	15.5	29
Soybean	14	14	5.0	9
		Dewahuwa, Yala 1986		
Rice	30	28	12.3	23
Chilli	35	33	11.9	22
Green gram	49	46	15.2	28
Soybean	35	33	14.4	27
		Kalankuttiya, Yala 1985		
Rice	64	52	22.4	45
Chilli	92	75	26.7	55
		Kalankuttiya, Yala 1986		
Rice	70	65	35.7	49
Chilli	86	80	37.8	51

In Dewahuwa there was little difference in the area planted to rice and green gram in the two seasons, but chilli accounted for 36 per cent of the area in 1985 and 22 per cent in 1986. The area planted to soybean increased from 9 to 27 per cent. This was in part due to the Agricultural Department and the Dewahuwa project manager encouraging soybean cultivation, and the Oil and Fats Corporation guaranteeing a minimum price of Rs 7.00/kg (US$1.00 = Rs 28.00) for soybean. The price actually received by the sample farmers exceeded Rs 9.00/kg on average. Rice accounted for 45 and 49 per cent of the total area of the sample farms in Kalankuttiya in 1985 and 1986, respectively, while chilli accounted for most of the remainder in both seasons. The data reported show the non-rice crops to be more profitable than rice (Tables 5 and 6).

Table 5. Crop costs and returns Dewahuwa, yala 1985 and 1986.

	Rice	Chilli	Green gram	Soybean
1985 yala				
No. of farms	35	41	42	14
Avg. area planted (ha)	0.37	0.47	0.37	0.36
Reported yield (kg/ha)	1300	900	600	1400
Gross returns (Rs/ha)	4968	27351	11772	12177
Production costs (Rs/ha)	3661	8386	3852	3232
Net returns (Rs/ha)	1307	18965	7920	8945
1986 yala				
No. of farms	30	35	49	35
Avg. area planted (ha)	0.41	0.34	0.31	0.41
Reported yield (kg/ha)	2292	1073	751	1853
Gross returns (Rs/ha)	7814	26265	12848	16863
Production costs (Rs/ha)	4339	13010	5682	4098
Net returns (Rs/ha)	3475	13255	7166	12765

US$1.00 = Rs 28.00

Table 6. Crop costs and returns Kalankuttiya, yala season 1985 and 1986.

	1985		1986	
	Rice	Chilli	Rice	Chilli
No. of farms	64	92	70	86
Avg. area planted (ha)	0.35	0.29	0.51	0.44
Reported yield (kg/ha)	2300	1900	3078	968
Gross returns (Rs/ha)	8937	53892	10436	25383
Production costs (Rs/ha)	5217	12820	5139	11505
Net Returns (Rs/ha)	3720	41072	5297	13878

US$ 1 = Rs. 28

This was especially true in 1985 when reported rice yields were very low, 1.3 and 2.3 tons/ha in Dewahuwa and Kalankuttiya, respectively. Rice yields, both as reported by farmers and estimated by crop cut samples, were somewhat higher in both locations in 1986. In Kalankuttiya in 1986, reported chilli yields and return to family resources were only 50 and 33 per cent of 1985 levels, respectively. Several factors may have contributed to the poor performance of chilli in 1986 yala. Heavy rains in April and early water issues saturated the soil, resulting in poor conditions for newly planted chilli. Some farmers who had planted chilli gave up and planted rice instead. Furthermore, disease damaged the chilli crop in 1986 but not in 1985. In 1986 the area planted to chilli was greater than 1985 (0.44 ha versus 0.29 ha) because farmers did not have to share their allotment with a bethma partner as in 1985. Finally, the price received for chilli was lower in 1986 which, along with the lower yields, contributed to much lower returns to farm resources. In 1986 the Cooperative Wholesale Establishment (CWE) graded chilli and rejected sub-standard produce. Many farmers sold their chilli to private traders who paid a lower price but bought all chilli offered.

Given the much greater profitability of non-rice crops (and particularly of chilli), the question arises as to why some farmers chose to produce rice. One answer to this question relates the crop grown to the soil drainage conditions. In Dewahuwa for 1985, OFC were planted on more than 96 per cent of the well-drained soils in both seasons (Table 7).

Table 7. Crops planted under different drainage conditions, yala 1985-86, Dewahuwa.

	Well-drained		Intermediate		Poorly-drained	
	1985	1986	1985	1986	1985	1986
Area of sample farms (ha)	17.2	21.1	28.5	17.0	8.0	15.1
Area planted to rice (%)	1.7	3.7	30.5	28.4	60.0	43.2
Area planted to OFC (%)	98.3	96.3	69.5	71.6	40.0	56.8
Chilli (%)	52.9	28.4	28.1	25.4	26.3	10.0
Green gram (%)	37.3	31.8	30.5	29.4	7.5	23.9
Soybean (%)	8.1	36.2	10.9	16.8	6.2	22.9

In 1985, OFC were planted on 40 per cent of the poorly-drained soils in the sample, and on 56 per cent in 1986. About 70 per cent in the intermediate drainage category were planted to OFC in both years. Rice was grown on a smaller percentage of each drainage category in Dewahuwa than Kalankuttiya, which is likely due to the water delivery schedule. In Dewahuwa, the plan called for farmers to receive water once in ten days; in Kalankuttiya once in seven. The data from Kalankuttiya in 1985 support the conclusion concerning the importance of soil drainage conditions in farmers' cropping decisions, and the correlation of crops with drainage class is more extreme than that in Dewahuwa. Over 90 per cent of the well-drained soils but none of the poorly-drained soils were planted to chilli (Table 8).

Table 8. Crops planted under different drainage conditions, yala 1985-86, Kalankuttiya.

	Well-drained		Intermediate		Poorly-drained	
	1985	1986	1985	1986	1985	1986
Area of sample farms (ha)	22.6	39.1	18.9	31.0	8.1	3.5
Area planted to rice (%)	6.7	28.9	68.8	69.1	100.0	89.7
Area planted to chilli (%)	93.3	71.1	31.2	30.9	0	10.3

Chilli production requires a much higher cash outlay than does rice. Average cash production costs per hectare for chilli are more than twice that for rice (Tables 9 and 10), while the cash production costs of green gram and soybean are approximately the same as for rice.

Table 9. Average cash production costs (in Rupees per hectare) for yala season crops, Dewahuwa, 1985-86.

Item	Rice	Chilli	Ratio[1]	Green gram	Ratio[2]	Soy-beans	Ratio[3]
1985 yala							
Fertilizer	701	1626	2.3	50	0.1	163	0.2
Pest & herb	153	1325	8.7	764	5.0	229	1.5
Seeds	0	158	-	488	-	532	-
Equipment*	1,446	1201	0.8	672	0.5	775	0.5
Labor*	916	3949	4.3	1526	1.7	1153	1.3
Land rent	445	127	0.3	352	0.8	380	0.9
Water cost**	0	2.7	-	0	-	0	-
Totals	3661	8389	2.3	3852	1.1	3232	0.9
1986 yala							
Fertilizer	788	2023	2.6	40	0.05	147	0.2
Pest & herb	181	2580	14.3	1053	5.8	381	2.1
Seeds	57	444	7.8	740	13.0	618	10.8
Equipment*	1234	1125	0.9	1043	0.8	160	0.1
Labor*	1345	6258	4.7	2356	1.8	2462	1.8
Land rent	734	580	0.8	450	0.6	330	0.4
Water cost**	7	78	11.1	0	-	0	-
Totals	4346	13088	3.0	5682	1.3	4098	0.9

US$1.00 = Rs28.00; [1]Chilli to rice, [2]Green gram to rice, [3]Soybean to rice; *Equipment and labor were hired; **includes payment for extra water issue in some cases and cost of pumping from drainage channels. Water costs do not include the O&M fee of Rs 250/ha, which none of the sample farmers reported having paid.

Table 10. Average cash production costs (in Rupees per hectare) for yala season crops, Kalankuttiya, 1985-86.

Item	1985 Rice	1985 Chilli	1985 Ratio	1986 Rice	1986 Chilli	1986 Ratio
Fert & pest	737	2287	3.1	804	2048	2.5
Herbicide	346	2317	6.7	420	2196	5.2
Seeds	219	583	2.7	67	548	8.2
Equipment*	1877	1755	0.9	1856	1358	0.7
Labor*	1139	4917	4.3	1432	4835	3.4
Land rent	899	961	1.1	560	520	0.9
Totals	5217	12820	2.5	5139	11505	2.2

US$1.00 = Rs28.00; Ratio = chilli to rice; *Equipment and labor were hired.

The higher cost of producing chilli is mainly due to greater use of fertilizers, pesticides, and hired labor. Despite this, the average size holding planted to chilli is not significantly different from that planted to other crops. This suggests that soil and related water management constraints were more important in the choice of crop than were credit or risk constraints associated with the higher cost of producing chilli.

The effects of location were analyzed by dividing the distributary units into head and tail sections. In Kalankuttiya in 1985, no differences in chilli yields were observed between farmers served by field channels located at the head of the distributary units as opposed to those located at the tails. For rice, however, significant yield differences were observed in the cases of two of the three distributary units (Tables 11 and 12).

Table 11. Crop yields (in kilograms per hectare) in head and tail portions of distributary channels, yala 1985-86, Kalankuttiya.

	Distributary channel	Head 1985	Head 1986	Tail 1985	Tail 1986
Rice	305 D2	2500	2890	2850	2970
	305 D3	2520*	2840	950	2040
	305 D4	3780*	3100	1720	3320
	305 D4		3720		3420
	305 D2		3570		2060
Chilli	305 D2	1730	1190	2110	970
	305 D3	1740	1120	1530	1200
	305 D4	1820	1200*	1980	340
	306 D4		870		690
	307 D2		810		840

* Row sample means are significantly different at the 0.05 probability level.

Table 12. Water deliveries (in millimeters per hectare) to distributary channels, and rice yields (in kilograms per hectare) in head and tail portions of these channels, yala 1985, Kalankuttiya.

Secondary channel	Water delivery	Rice yield	
		Head	Tail
D2	1604	2500	2850
D3	1151	2520*	950*
D4	1298	3780*	1720*

*Row sample means are significantly different at the 0.05 probability level.

The positive relationship shown in Table 12 between the water deliveries at the head of the distributary channel and rice yields in the tail portions suggests that differences in water supply may have caused these differences. The channel with no significant difference in yields between the head and tail ends (D2) received the largest amount of water due to a leaking head-gate. In Dewahuwa, also in 1985, rice yields in head end plots were significantly higher than those in tail end plots (Table 13). There was no significant difference in OFC yields between head and tail plots, however.

Table 13. Yields (in kilograms per hectare) in head and tail portions of the distributary channels in Dewahuwa.

	Head		Tail	
	1985	1986	1985	1986
Rice	1759*	2282	933	2313
Chilli	973	1122	761	946
Green gram	657	794	631	677
Soybean	1518	1848	1188	1859

*Significantly different at 0.05 probability level.

These results suggest that when irrigation water deliveries are scheduled to support the production of upland crops such as chilli, a farmer with poorly-drained soils in the tail end of the secondary may face severe problems. Because of poorly drained soil and generally poor water control, he is unable to successfully grow chilli. At the same time, the amount of water he receives is severely inadequate for rice.

The 1985 data for rice cultivation in Kalankuttiya showed that compared with the rest of the sample farmers, the farmers in the two tail sections where yields were significantly lower used less purchased inputs of fertilizer and pesticides. These same farmers, however, spent more on hired equipment for land preparation (Table 14). These findings are consistent with a strategy of reducing cash outlays in order to reduce the risk of financial losses. The greater amount spent for hired equipment for land preparation

Table 14. Cost and returns (in Rupees per hectare) for rice production on sample farms in the tail portion of distributary channels D3 and D4 compared with all other sample farmers, yala 1985, Kalankuttiya.

	Sample farms	All other farms
Fertilizer	186***	937***
Pesticide and herbicide	54***	451***
Hired equipment	2365***	1701***
Seeds and seedlings	397***	154***
Payments for water	30	46
Hired labor excluding harvest	373	524
Hired labor for harvest	448*	732*
Land rental	1015	859
Total cash costs	4868	5404
Gross returns	5667***	10128***
Net returns to family resources (US$/ha)	799***	4725***
Net returns to family labor (US$/man-day)	9**	80**

US$1.00 = Rs28.00; row sample means are significantly different at the following probability levels: * = 0.1, ** = 0.05, and *** = 0.01.

probably reflects the difficulties that these farmers face in achieving timely land preparation. Delays in water issues may force them either to begin land preparation under somewhat dry conditions (in which case the amount of power needed would be greater) or to complete land preparation in a shorter time than available to farmers with more favorable water conditions.

These findings indicate that because of reduced input levels, the reduction in yield associated with unfavorable water conditions may be considerably greater than the amount that would be attributable to the physiological impact of water stress alone. They also indicate that in spite of reduced chemical input use, a farmer's total cash outlay may not be significantly below that of a farmer with favorable water conditions. The net result of these conditions is very low returns to the farmer's resources (Table 14).

In 1986 yala in Kalankuttiya, there was no significant difference between yields at the head and tail for rice. For one D-channel, chilli yields were significantly different between head and tail end plots. In the same season in Dewahuwa there was no significant difference in yields at the head and for any of the crops. This may be due to the fact that more water was supplied in 1986 than in 1985.

INSTITUTIONAL ASPECTS OF CROP DECISIONS[a]

In both Dewahuwa and Kalankuttiya, farmers prefer to grow a non-rice crop during yala and most commonly chilli. Rice is grown not so much by choice, as by (perceived) necessity. The primary reason that farmers prefer to grow chilli is the high guaranteed commodity price of Rs 26-28/kg. The reasons that some farmers do not grow chilli involve a complex of physical factors (e.g., soil types and water availability) as well as economic and institutional factors, of which the following appear to be important: financing and credit, labor availability, land tenure, and farmers' knowledge of water issues.

Financing

After soil and water, credit appears to be the single most important determinant in farmers' crop decisions. To finance the yala crop, farmers depend upon the sales of their maha rice; otherwise they must seek credit if they have no other source of income. Since yala begins just after the Sinhala New Year (April), farmers are often short of cash. And because a good portion of the maha crop goes for the family's subsistence needs, there is not normally enough left over to finance all the inputs needed for yala. Bank credit is often problematic because so many farmers have defaulted on previous loans. During 1986 yala, additional credit was made available, but generally this happened after crop decisions had been made.

Most farmers must rely on private credit or third party financing for at least some of their inputs. The prohibitive interest rates on private loans (20 per cent/month is typical) induce cash-poor landowners to mortgage their land and/or enter into sharecropping arrangements whereby inputs are paid though a third party. In Dewahuwa, nearly one third of the sample operators were farming mortgaged land; another third were farming under sharecropping (<u>ande</u>) contracts (Bulankulame 1986). Farmers who are using outside financing have extra incentive, as well as the means, to pay for the inputs necessary for chilli cultivation. Farmers who rely upon household resources, on the other hand, may be more likely to opt for rice.[4]

Labor Availability

The fact that chilli cultivation uses 3.4 times as much labor as does rice cultivation indicates the importance of the household labor pool, size of landholding, or adequate financing to hire the labor needed. Many farmers grow chilli on only one part of their holdings because they cannot afford to plant the entire area to such an expensive crop. Where land holdings are small (as in the case of a large family sharing a single 2.5 acre allotment in Mahaweli H), neither labor nor credit is a binding constraint, and there is an incentive to gain maximum profit from a small area. The crop of choice would be chilli.

Labor constraints in Kalankuttiya were more acute during yala 1986 than 1985 because of the alternating bethma practice from year to year. During yala 1985 only half the command area of each distributary channel was irrigated and the land was shared equitably among all farmers with each owner cultivating 50 per cent of his normal area. The labor supply was effectively doubled within each distributary command area as a result. Bethma divisions were not in effect during 1986 yala. That the difference in labor availability between the two yala seasons is not more pronounced in the relative proportions of land cultivated in chilli (55 per cent in 1985 versus 51 per cent in 1986) may be due to mutually compensating factors. The excellent 1985 chilli harvest and high support price may have outweighed the labor shortage in farmers' crop decisions, even at the cost of higher wage rates.

Land Tenure

Farmers who leased-in land during yala paid about 50 per cent/hectare more for well-drained land than for poorly-drained land, reflecting the greater value of non-rice crops. At the same time, having paid a higher rent, the farmer had an incentive to recover his costs through a high income crop such as chilli. The location of the plot can also be important. In Dewahuwa, where bethma divisions are practiced every yala, those farmers who are allocated temporary plots far away from their own fields seem to be more likely to grow rice than are those who cultivate in their usual locations. The reason would be to minimize the need to visit their fields: rice can grow with relatively little attention, while chilli must be looked after closely.

Knowledge of Water Issues

Farmers who anticipate water problems are unlikely to grow either rice or chilli; instead, they would select short-duration varieties of non-rice crops like soybean or green gram. As a result, farmers who normally cultivate in the tail end or who have been given a tail end bethma allotment, are more likely to rent-out their land during yala. Because of the many factors involved in farmers' crop decisions, there is a tendency to wait until the last minute, or even later, to decide. One farmer who was growing six different crops, including chilli and rice, reported that his original intention was to grow only chilli. Due to heavy rains, however, his chilli crop needed replanting. With neither enough time to grow another chilli nursery, nor finances to purchase chilli plants, he planted green gram, cowpea, onion, and vegetables to replace the damaged crop. Another farmer who had decided to grow chilli instead of rice changed his mind after heavy rain waterlogged his fields; he switched back to rice.

One factor with regard to farmers' willingness to grow diversified crops is their level of knowledge about cultivation. In Dewahuwa nearly all farmers are involved in some rain-fed agriculture, either in <u>chena</u> cultivation (usually encroached) or in their 1.2 ha house plots. Their experience in growing non-rice crops in these plots can be readily transferred to irrigated conditions, albeit with some technical advice. The function of extension agents is to provide information about market prices and optimal input use; the basic cultivation practices are already well understood by the majority of farmers. In Mahaweli, most farmers are not engaged in rain-fed farming, and this may help explain why they are more single-minded about chilli as nearly the only non-rice crop; promoting different crops through extension might result in a further expansion of non-rice cultivation.

NOTES

1. Members of the IIMI Crop Diversification Group include S.M. Miranda, E. Martin, and D.G. Groenfeldt. Their assistance is much appreciated.

2. OFC refers to "other field crops," such as chilli, green gram, soybean and black gram.

3. Based on information gathered through unstructured interviews during yala 1986 and through questionnaires administered during maha 1985/86 in Dewahuwa and Mahaweli H-2, Block 305; analysis of questionnaires administered during yala 1986 is currently underway.

4. The relationship between financing and crop selection, as well as other relationships, will be tested as the 1986 yala data are analyzed.

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