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MARD PROJECT

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ON-FARM DRAINAGE
IN
MAHAWELI SYSTEM B

by

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MARD PROJECT
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EXECUTIVE SUMMARY

A pilot/research project to investigate the effect of subsurface drainage system as a suitable alternative to alleviate the water logging problem was conducted at three locations in Mahaweli System B. Construction work commenced in April 1992 and was completed at RARC site, Sapukotuna Farm and Bogaswewa in June, September and November 1992 respectively.

During the construction period, a training workshop was conducted for two days for 25 participants including DRPM/Water Management, Irrigation Engineers, Engineering Assistants to introduce techniques to solve on-farm drainage problems in System B.

The main objective in conducting this study was to find the effectiveness of subsurface drainage system in maintaining the water table below the root zone throughout the year to facilitate the cultivation of OFCs.

At the RARC site, flumes were installed to measure the irrigation inflow into terraces. Outflow from each drain line was taken at hourly intervals during day time. Two lines of observation wells were installed upto about 1 m depth to monitor the daily ground water table depths. Daily rainfall and the evaporation pan data during the study period were obtained from the meteorological station at the RARC.

It was observed at the RARC site that a total of 13 different crops, grown at the drainage site performed well during both seasons indicating the effectiveness of the subsurface drainage system in eliminating one of the water management constraint for the successful cultivation of OFCs in System B. The following conclusion can be made, based on the results of the monitoring study.

- Canal seepage contribute to water table build up during the Yala season.
- High surface irrigation efficiency can be attained in NCB soils.
- OFCs can be grown in Yala season without subsurface drainage if there are no serious seepage problems from irrigation canals and from paddy fields.
- Filter material is not required at tile junctions if the soil is stable.
- It is not possible to grow OFCs successfully during Maha season in the absence of proper drainage facilities except in the highground.
- Much of the excess water from heavy rains in the Maha season is removed as subsurface flow compared surface runoff.
- Hooghoudt equation can be used for drainage designs in System B

At the Sapukotuna farm, only the fluctuation of water table was monitored. The results indicated that the water logging problem could not be solved satisfactorily at the Sapukotuna farm as a results of,

- Heavy seepage from the unlined D-canal,
- Deep cuts in preparing the level terraces in a land with 8-9% slope,
- Poor land smoothing,
- Uncleared main drain, and
- inadequacy of three interceptor drain.

The following recommendations are made to improve the drainage problems in System B.

- Seepage problem can be overcome in the Yala season by constructing interceptor drains across the slope and parallel to irrigation canal. In the case of paddy, drains should be constructed at the boundary between paddy and OFCs.
- Cultivation of OFCs should not be promoted in the Maha season unless proper subsurface or surface drainage facilities are available.
- Higher grounds with deep soils and no seepage or water logging problems should be selected initially for the promotion of OFCs.
- Flat areas at the bottom of the catena should be set aside for paddy cultivation only.
- Training of officials and farmers on on-farm drainage should continue. Installation of observation wells in the OFC cultivated areas in farmers fields, as practised in 1988 in System B, should be re-introduced.
- Support should be provided to RARC to continue the drainage study for few more years in order to confirm the results and to identify any problems with regard to maintenance.
- The subsurface drainage facilities should be extended to few more farmers who are willing to grow OFCs throughout the year. A suitable subsidy programme, perhaps to cover the cost of tiles, would encourage more farmers to adopt subsurface drainage.
- Review the procedure of land alienation in large blocks to the commercial farmers. It should be made mandatory for any potential commercial farmer to submit a detailed development plan of the farm along with the financial proposal for approval.

INTRODUCTION

BACKGROUND

Drainage has been identified as one of the major constraints for the successful cultivation of Other Field Crops (OFCs) since the inception of the Mahaweli System B. Investigation work on drainage was initiated in 1988 and continued until 1989 (Henderson, 1988, 1989). Raised beds of 20 cm was recommended as one of the major out come of the above work. However, the introduction of 20 cm raised beds did not help to alleviate the water logging problem, specially during the Maha season. A team of two consultants were assigned in November 1991 to further investigate and recommend solutions to the drainage problems in Mahaweli System B. Their findings were reported in two separate reports (Doering, 1992; Gunawardena, 1992).

New investigations in addition to the pervious work has helped to identify the causes of water logging in Mahaweli System B. It was strongly recommended by both consultants to initiate a pilot/research project to investigate the drainage problems and provide recommendations. Subsurface drainage has been identified as a suitable alternative to alleviate the water logging problem. Three locations were selected to conducted the study. The details of the locations were given by Doering .(1992) and Gunawardena (1992). A total of 36 days, spread over a period of 8 months (from April 1992 to December 1992) were allocated to continue the pilot project. The specific tasks of the consultancy is given below.

TASKS

- Assist in procurement of materials for installation of subsurface drainage
- Setting out subsurface drains at three locations
- Supervise the installations of subsurface drains
- Train System B personnel on Design, layout and Installation of subsurface drains
- Prepare detail methodology and procedure for data collection and analysis of the drainage monitoring study.
- Assist in the experimental layout and installation of flumes, observation wells, etc.
- Presentation of findings, recommendations and report writing

INSTALLATION OF SUBSURFACE DRAINAGE SYSTEMS

Preliminary designs were completed during the first assignment after the field investigation. Few modifications were included later since some of the problems were not envisaged at the beginning. For example, a farmer at Bogaswewa refused to send the drainage outlet via his land to the turnout drainage channel along the shortest way. Hence, the lay out was adjusted accordingly. Detail designs including the bills of quantities for three sites were handed over to the Water Management Engineer at MARD who attended to the formalities of handing over the construction to a contractor.

RARC was identified as the priority site and the construction work commenced in April 1992. The consultant monitored the construction of the drainage system, including laying out the drainage lines, checking the gradient along the slope, placing pipe drains, filter material and backfilling. The persons involved in the construction in addition to the water management staff at the RARC gained experience in this work. Later the same crew was used to construct the drainage systems at Sapukotona farm and Bogaswewa with hardly any supervision. The construction work was completed at RARC site, Sapukotuna Farm and Bogaswewa in June, September and November 1992 respectively.

TRAINING OF SYSTEM B PERSONNEL

A training workshop was conducted for two days for 25 participants at the Mahaweli Regional Training Centre, Hansayapalama on 23rd and 24th September 1992. The objective of the training workshop was to introduce techniques to solve on-farm drainage problems in System B. Water management staff of the System B including DRPM/Water Management, Irrigation Engineers, Engineering Assistants participated in the programme. It has been proved that a training workshop of this nature could not be conducted more than two day period for such a group of people since the demand on their time for day to day operation of the System B is very high. Therefore, the consultant had a difficult task of disseminating knowledge within a limited time period. To overcome this problem, training materials were prepared and handed over to the participants at the beginning of the workshop. Topics of the nine handouts prepared are given below. One such handout (no.4) is given in Annex 1.

Lesson No	Topic
1	Agricultural Drainage
2	Principles of Drainage
3	Drainage Investigation
4	Determination of Drainage Spacing
5	Interceptor Drainage
6	Drainage Materials and Auxiliaries
7	Construction
8	Salinization and Drainage
9	Operation and Maintenance of Drainage Systems

Handouts can later be used as reference material for drainage design work as well as for training materials since the information included were exclusively prepared based on the data gathered from System B. A field trip was arranged to the drainage monitoring sites at RARC and Sapukotuna Farm.

DRAINAGE MONITORING STUDY

Soon after the completion of the construction of drainage system at RARC, instruments were installed and the monitoring work was commenced in the last week of June 1992. The installation and monitoring work were conducted by the personnel assigned by the MARD under the supervision of Mr. Ajantha de Silva, Research officer in water management at the RARC. The consultant has assisted him in the preparation of detailed methodology, experimental layout, installation of flumes, observation wells, etc. The format for data collection, data entry to the computer and preliminary analysis of the drainage monitoring study were done with the relevant staff of the RARC. An undergraduate was assigned to the project for a period of three months during the Maha season to help with the data collection work.

Monitoring at the Sapukotuna farm was initiated at the beginning of the Maha season in October. No systematic data collection was done at Bogaswewa since there was a delay in the construction. The next two chapters presents the details of the monitoring studies at RARC and Sapukotuna farm respectively.

DRAINAGE MONITORING STUDY AT THE RARC SITE

INTRODUCTION

Background

The location identified at the RARC had a continuous water logging problem during both Yala and Maha seasons. As a result only paddy was grown in this land. Preliminary investigation indicated that the canal seepage was responsible for this water logging problem (Gunawardena, 1992) which was aggravated further during the Maha season due to heavy rainfall. Therefore, this land was identified as a suitable location for the installation of subsurface drainage.

Installation of subsurface drains

Seven subsurface drainage lines (SD1, SD2, SD3 etc.) were installed as shown in Figure 1. These were placed about 0.7 - 1 m depth. A slope of 0.3% was maintained along the lines towards the outlets. Lines SD4 and SD6 were installed without envelop materials to find any differences in their performance with the rest of pipes. Difficulties were encountered in burying the pipe number SD1 because of heavy seepage and the unstable soil.

OBJECTIVES

The main objective in conducting this monitoring study was to find the effectiveness of subsurface drainage system in maintaining the water table below the root zone throughout the year in order to facilitate the cultivation of OFCs. Verifying drainage design criteria to provide guidelines and recommendations and to estimate the different components of the water balance equation to assess the effectiveness of water application systems in controlling the water table are the additional specific objectives of the study.

METHODOLOGY

Study site

The layout of the study site is given in Figure 1. Details of the crops, extent and irrigation method adopted are given in Table 1. During the Maha season, an assortment of crops given in Table 2 were grown.

Figure 1. Layout of RARC site

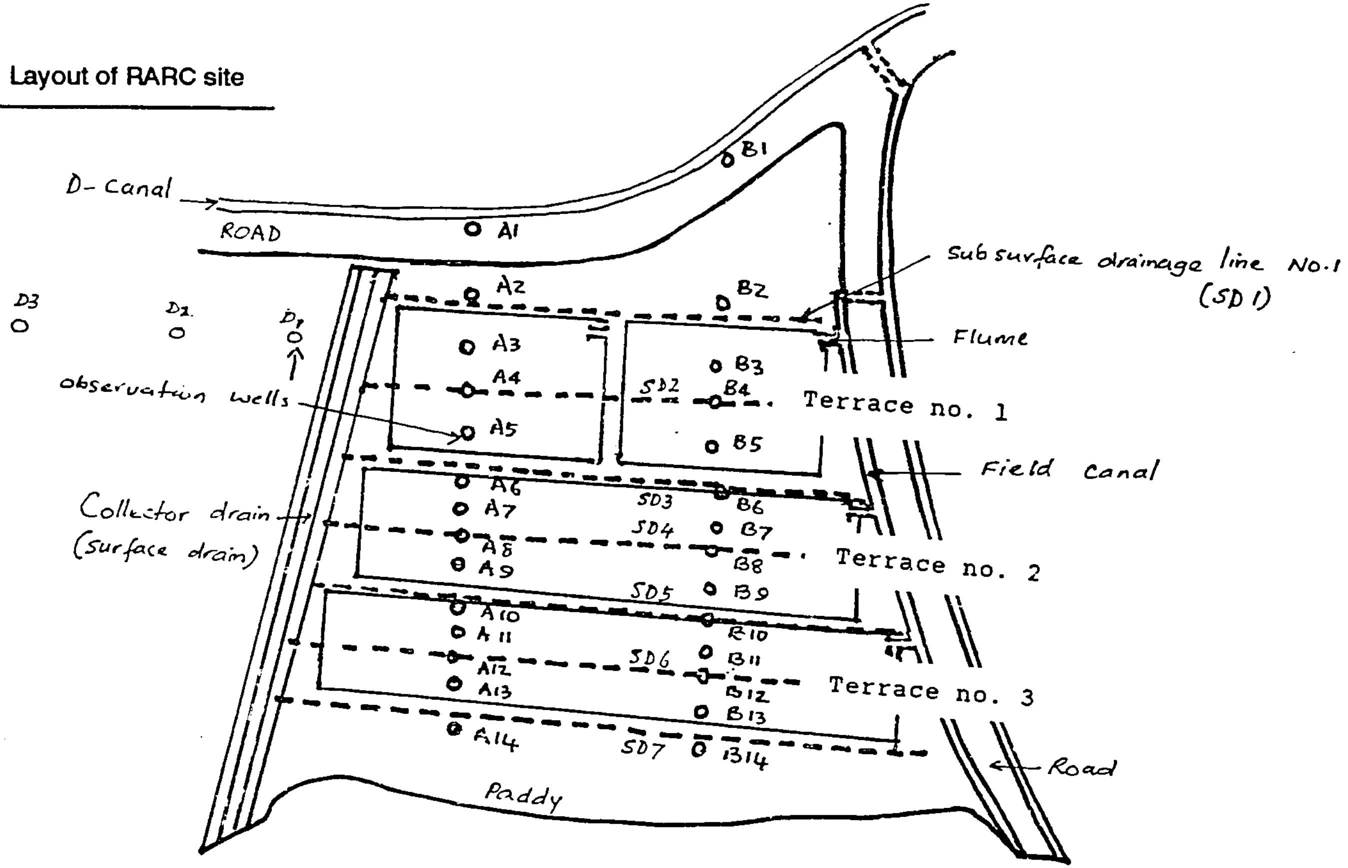


Table 1. Area allocated for each crops in different terraces in Yala 1992

Crop	Terrace	Irrigation Method	Date of Planting	Area (m^2)
Ground Nut	1	Ridge and Furrow	26.06.1992	467.4
B-Onion	1	Raised Beds	26.06.1992	594.7
Melon	2	Ridge and Furrow	26.06.1992	1067.6
Melon	3	Raised Beds	26.06.1992	1200.5

Table 2. Crops grown in Maha season 1992/93

Crop	Terrace	Irrigation Method	Date of planting
Baby Corn	1	Ridge and Furrow	02/11/1992
Okra	1	Raised Beds	10/11/1992
Batana	1	Raised Beds	17/11/1992
Squash	1	Raised Beds	17/11/1992
Beans	2	Raised Beds	10/11/1992
Carrot	2	Raised Beds	10/11/1992
Tomato	2	Raised Beds	18/11/1992
Beet	2	Raised Beds	19/11/1992
Cabbage	2	Raised Beds	20/11/192
Groundnut	3	Ridge and Furrow	13/11/1992
Capsicum	3	Ridge and Furrow	24/11/1992

Measurement of surface inflow and outflow

Flumes were installed to measure the irrigation inflow into terraces as shown in Figure 1. The average depth of flow, time at the beginning and at the end of irrigation were recorded. A calibration curve developed by the water management staff at the RARC was used to convert the depth of flow into discharge. There were no outflow during the Yala season as a result of careful monitoring of irrigation issues. It was not possible to monitor the surface outflow during heavy rainstorms in the Maha season mainly due to lack of automatic recording equipments and the inadequate capacity of the flumes.

Measurement of drainflow

Outflow from each drain line was taken 8 times a day at hourly intervals between 7 am to 3 pm. These hourly readings were taken using a polythene bag which collects the drain discharge for a duration of about 10 seconds. This collected water was poured into a measuring cylinder and the rate of discharge was calculated. This rate was multiplied by the interval between two measurements to estimate the volume of discharge.

Ground water table

Two lines of observation wells were installed upto about 1 m depth to monitor the ground water table depths on daily basis. The location of wells are shown in Figure 1. Few wells along a line (D) extending away from the main drain parallel to A3-B3 was established to monitor the water table without drainage.

Meteorological data

Daily rainfall and the evaporation pan data during the study period were obtained from the meteorological station at the RARC.

RESULTS DURING YALA SEASON (25/06/1992 to 24/09/1992)

The results presented in this report extended beyond the period of consultancy in order to include both Yala and Maha seasons. A large amount of data were gathered during the monitoring study. All the results were analyzed in order arrive at conclusions. However, the abstract results, which may be useful for the drainage work in System B is given in this report.

Water table

The average of 10 water table observation wells along the line B-B during the period from 3rd August tc 30th September is shown in Figure 2. The water table was maintained below the critical level of 50 cm during this period. It was observed that the peaks of the water table coincided with the irrigation issues. Rainfall during this period was 1.8 mm and hence considered negligible.

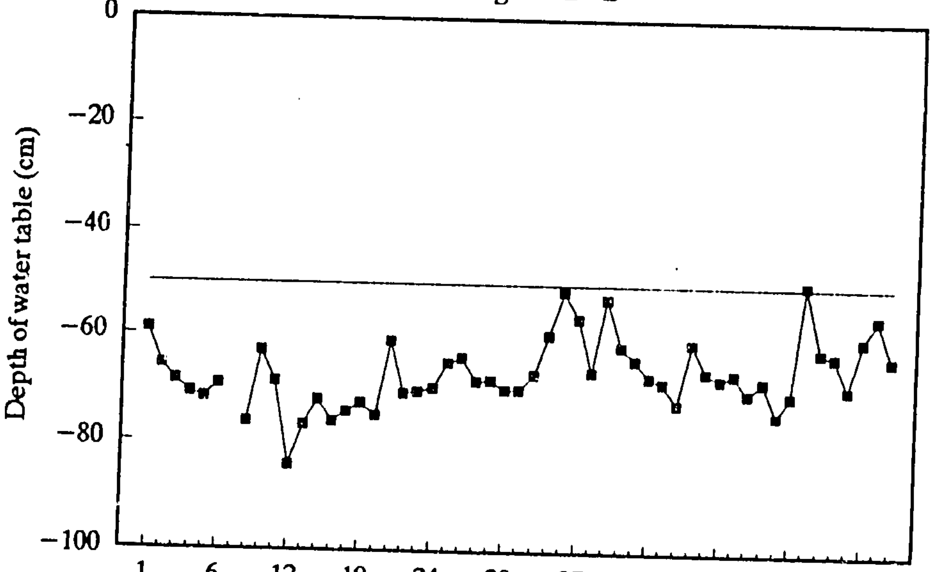
Drainflow

The total darinflow from each line from 25th June to 24th September 1992 is shown in Figure 3. The highest amount of flow was observed from SD1, which implies that this line intercepted much of the seepage water from the distributary canal. The second highest flow was recorded from SD7. This line was located at the boundary between the study site and the adjacent paddy field. This line intercepted the seepage from the paddy field thus giving a substantially higher value compared to the other lines except line SD1.

Drain lines SD2, SD4, and SD6 yield less flow since they discharged excess water only after the irrigation issues. Number SD3 and SD5 are located just below the boundaries of terrace 1 and 2 and hence were comparatively at a lower elevation with respect to line SD2 and SD4 respectively. Lines SD3 and SD5 collected seepage water which was not intercepted by the line SD1.

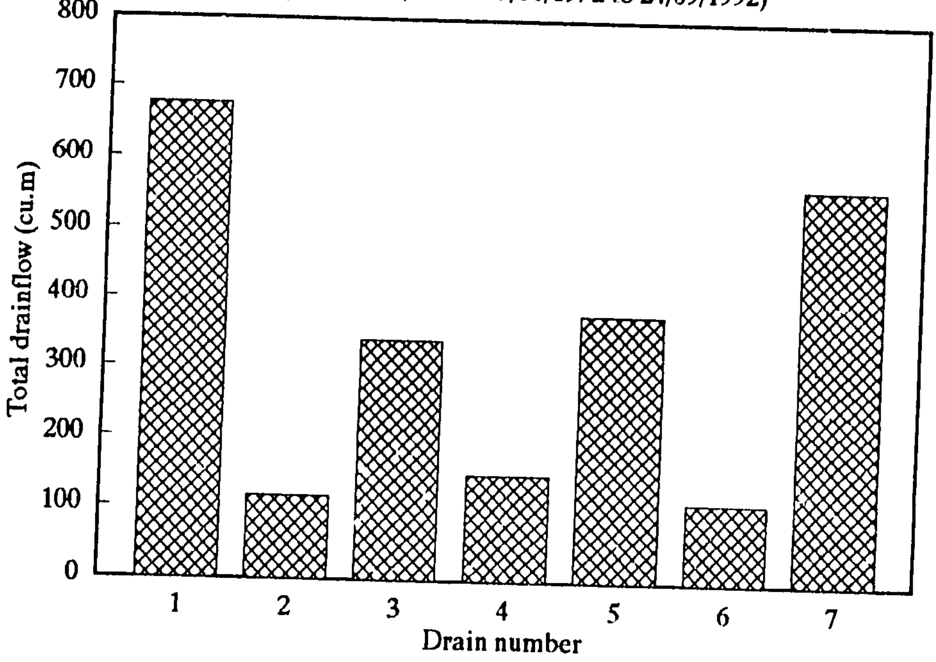
The drainflow from lines SD2 (with filter), SD4 and SD6 (without filter) were similar. Hence there is no significant effect of improved performance due to filter materials.

Figure 2. Depth of water table at RARC site (Yala 1992) along line B–B



Day 1 starts on 03rd August 1992

Figure 3. Drainflow from sub–surface drains at RARC site (Yala 1992, From 25/06/1992 to 24/09/1992)



Irrigation Efficiency

The total irrigation from 25th June to 24th September for all the crops grown in the study site was estimated by adding all the irrigation issues during this period and dividing the volume by the cultivated extent. Pan evaporation data were multiplied by the pan coefficient to estimate the consumptive use for the same period. Irrigation efficiency was calculated by dividing the consumptive use by the total depth of irrigation. The results are given below.

Consumptive use during Yala season = 564 mm
Total irrigation during Yala season = 811 mm
Irrigation efficiency = 564*100/811
= 69.5%

This shows that a much higher application efficiency can be achieved even in NCB soils if the recommended scheduling is adopted.

Seepage

Seepage from the irrigation canal was estimated using a simple water balance equation. It was assumed that the excess water from irrigation and seepage from the irrigation canal contributed to the drain flow. The results of the seepage estimates are given below

Consumptive use = 1878 m^3
Total Irrigation = 2700 m^3
Total Drainage flow = 2338 m^3
Seepage during the season = 2338 - (2700-1878)
= 1516 m^3

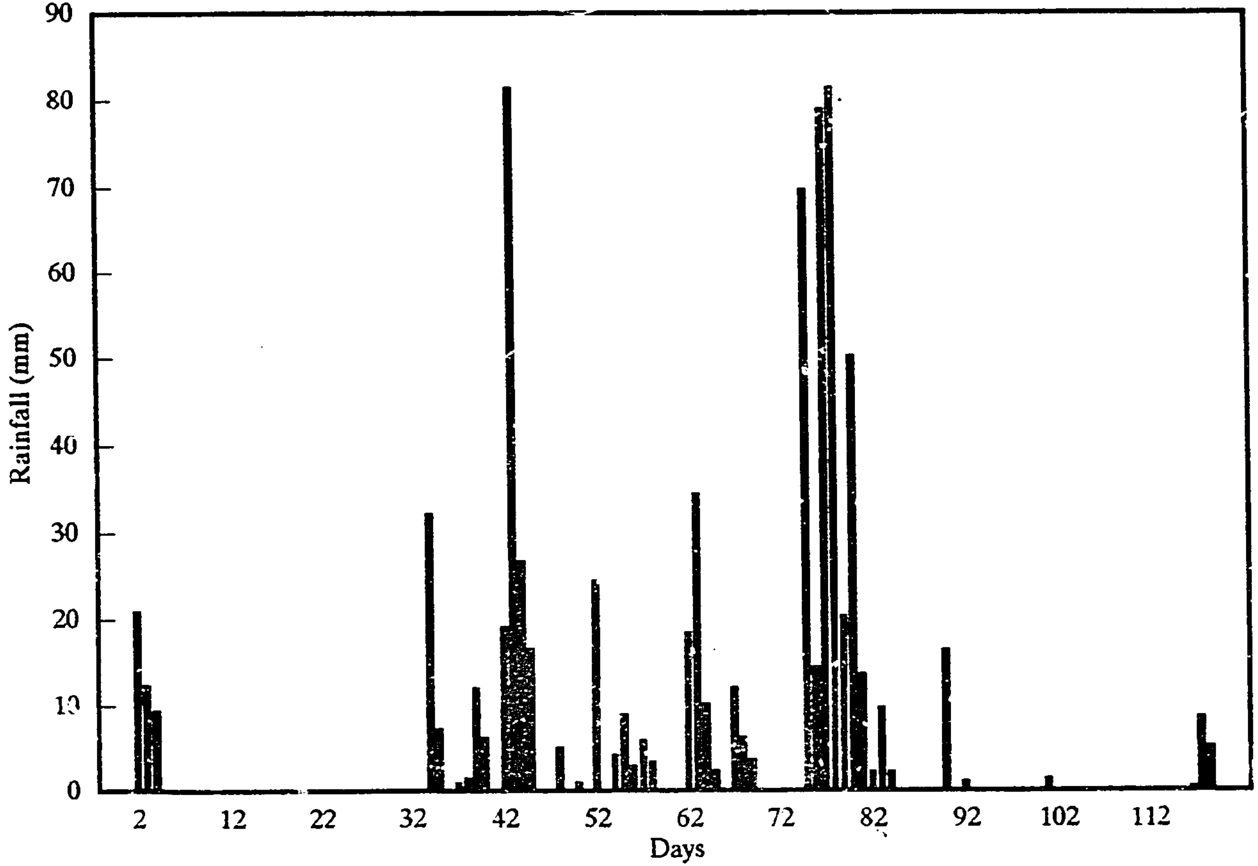
Duration of the season = 91 days
Length of the canal = 67 m
Therefore,
Seepage rate per unit length = 1516/(91*67)
= 0.25 $m^3/d/m$

RESULTS DURING MAHA SEASON (01/10/1992 to 30/01/1993)

Rainfall

Daily rainfall at RARC during the Maha season 1992/93 is shown in Figure 4. The total rainfall during this period was 769.2 mm. In addition to the amount, the distribution of rainfall determines the severity of drainage problem. For example, a total of 344 mm of rainfall has occurred during 10 consecutive days from 14/12/1992 to 32/12/1992. This rain sequence could have destroyed the crop due to prolong saturation of the root zone if the drainage system was not in place.

Figure 4. Daily rainfall at RARC site (Maha 1992/93)



Day 1 starts on 1st October 1992

Drainflow

Drainflow has increased with the onset of the Maha season mainly due to high rainfall. The total drainflow during the month of November is 1336 m^3. The percentage of rainfall removed as subsurface flow is about 80% assuming that the seepage from the canal remains the same as in the Yala season. This shows the usefulness of subsurface drainage system in removing the excess water from rainfall.

Water Table

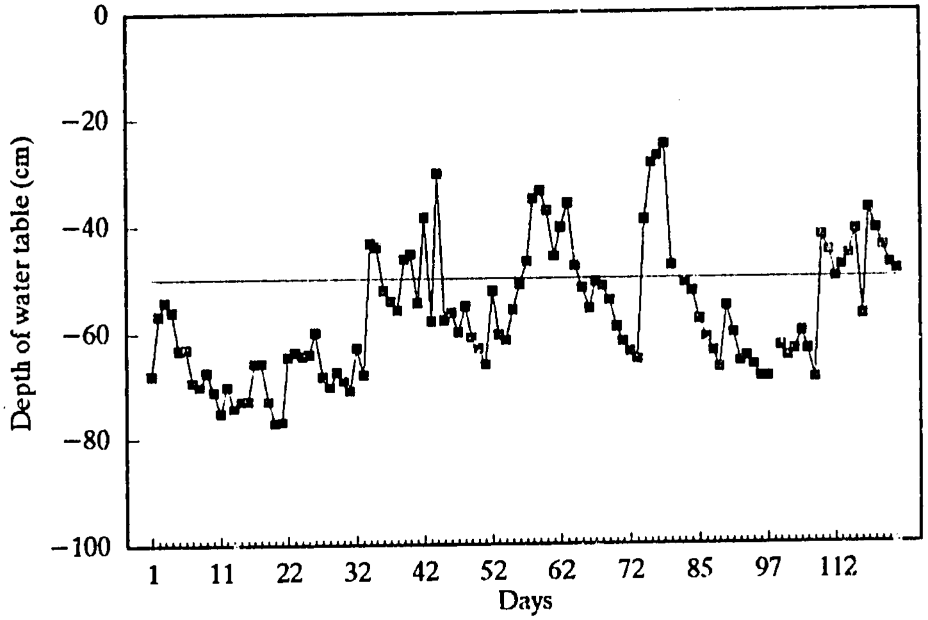
The average of 10 water table observation wells along the line B-B during the period from 1st October 1992 to 30th January 1993 is shown in Figure 5. The water table was maintained below the critical level of 50 cm during much of the time during the season. The water table reached the root zone when there were heavy rains. However, the water table receded fairly quickly below the root zone thus avoiding a serious stress on the crop. The water table could have built up if the excess water was not removed quickly before the onset of the next rain event.

Figure 6 shows the effect of subsurface drainage system on the water table during the Maha season. These two wells were located at a same distance from the main drainage channel. One was (B3) located in the drainage site while the other (D3) was located in a field without subsurface drainage. It is apparent that the water table in the non-drainage site was within the root zone throughout the Maha season while the water table at the drainage site was below the root zone during much of the time. This shows that the subsurface drainage system at the RARC site has kept the water table below the root zone during the season.

VALIDITY OF THE DRAINAGE DESIGN CRITERIA

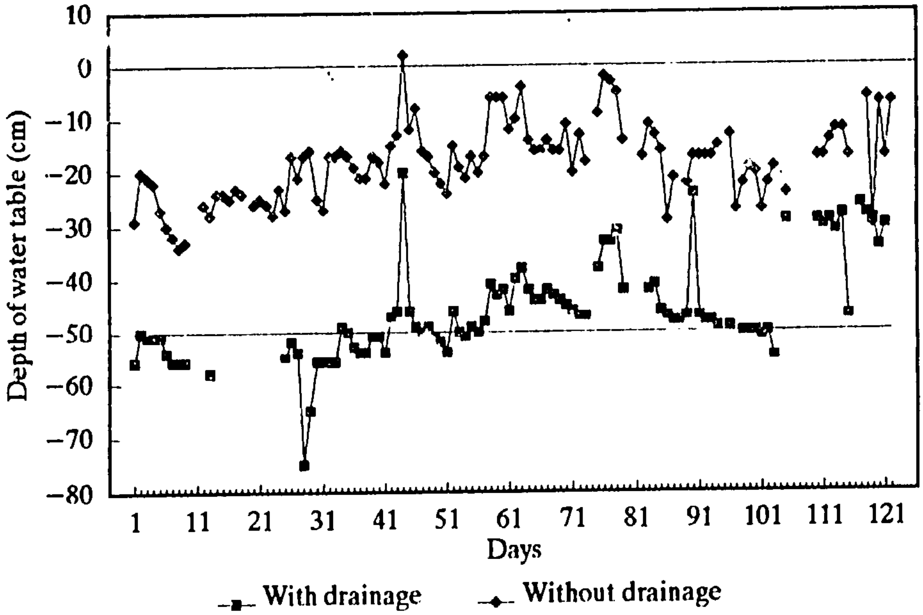
Drainage criteria for on-farm drainage have not been available for the irrigation systems in Sri Lanka. Considering the assumptions used in developing drainage design equations, the Hooghoudt equation was considered as the most suitable one to use in determining the drainage spacing. Therefore it was used for the designs in this study. The results indicated that the installed drainage system has kept the water table below the critical root zone depth (50 cm) during both Yala and Maha seasons. Hence, it is recommended to use the Hooghoudt equation for drainage designs in the Mahaweli System B. Horizontal flow and less seepage face due to shallow soils, less slope and high hydraulic conductivity of the System B agrees with the assumptions made in the Hooghoudt equation. Procedure of determining the drainage spacing using the Hooghoudt equation is given in Annex 1. With regard to the information required, it

Figure 5. Depth of water table at RARC site (Maha 1992/93) along line B – B



Day 1 starts on 1st October 1992

Figure 6. Comparison of water table depths with and without drainage at RARC site (Maha 1992/93)



Day 1 starts on 1st October 1992

will not be difficult to determine the hydraulic conductivity, depth to impervious layer and the depth of root zone. However, the estimation of recharge has be done with more care since this variable can be estimated with different approaches and the assumptions made may be too far from reality.

CONCLUSIONS

It was observed that all the crops listed in Table 1 and 2 performed well during both seasons thus indicating the effectiveness of the subsurface drainage system in removing one of the water management constraints for the successful cultivation of OFCs in System B. The following conclusion can be made based on the results of the monitoring study, supported by some of the previous investigations conducted in System B.

- Canal seepage contribute to water table build up during the Yala season.
- High surface irrigation efficiency can be attained in NCB soils.
- OFCs can be grown in Yala season without subsurface drainage if there are no serious seepage problems from irrigation canals and from paddy fields.
- Filter material is not required at the tile junctions if the soil is stable.
- It is not possible to grow OFCs without any yield loss during Maha season in the absence of proper drainage facilities except in the highground.
- Much of the excess water from heavy rains in Maha season is removed through subsurface flow compared surface runoff.
- Hooghoudt equation can be used for drainage designs in System .B

RECOMMENDATIONS

- Seepage problem can be overcome in the Yala season by constructing interceptor drains across the slope and parallel to irrigation canal. In the case of paddy, drains should be constructed at the boundary between paddy and OFCs.
- Cultivation of OFCs should not be promoted in the Maha season unless proper subsurface or surface drainage facilities are available.

- Higher grounds with deep soils and no seepage or water logging problems should be selected initially for the promotion of OFCs.

- Flat areas at the bottom of the catena should be set aside for paddy cultivation only.

- Training of officials and farmers on on-farm drainage should continue. Installation of observation wells in the OFC cultivated areas in farmers fields, as practised in 1988 in System B, should be re-introduced.

- Support should be provided to RARC to continue the drainage study for few more years in order to confirm the results and to identify any problems with regard to maintenance.

- The subsurface drainage facilities should be extended to few more farmers who are willing to grow OFCs throughout the year. A subsidy scheme, perhaps to cover the cost of tiles, may encourage more farmers to adopt subsurface drainage.

DRAINAGE MONITORING STUDY AT SAPUKOTUNA FARM

INTRODUCTION

Background

The Sapukotuna farm had a continuous water logging problem during both Yala and Maha seasons. The source of excess water was primarily from the unlined D-canal which parallel the top of the farm. The original slope of the land was about 8-9%. There were deep cuts ranging from 50 to 100 cm in preparing the level terraces. As a consequence of the deep cuts, the inside edge of the terrace basins extend into the water table surfaces. The details of investigation are given by Doering (1992).

Installation of subsurface drains

In order to solve the drainage problem, three interceptor drains, as shown in Figure 2, were constructed. The design specifications are given by Gunawardena (1992). However, the design of outfall structures were changed at the construction stage, perhaps to save cost. Difficulties were encountered in burying the pipe number three because of heavy seepage and the unstable soil. Problem was partly solved by placing sand in the bottom of the trench during the construction.

OBJECTIVE

The main objective in conducting this monitoring study was to find the effectiveness of subsurface drainage system in maintaining the water table below the root zone throughout the year in order to facilitate the cultivation of OFCs.

METHODOLOGY

The layout of the study site is given in Figure 7. Water melons and onions were grown during the Maha season. Observation wells were installed along three lines as shown in Figure 7. The water table measurements were taken on daily basis.

RESULTS AND DISCUSSIONS

The average water table along lines A-A, B-B and C-C during the Maha season are give in Figure 8a, 8b, and 8c respectively. The results showed that the water table was below the critical root zone depth at the terraces where the sub-surface drains were installed. Usually, the interceptor drains cut off the lateral flow and reduces the water table level at the down slope. However, the high head in pervious soils tend to bring the water table to the surface just below the sub-surface drains. It will be difficult to keep the water table below the root zone without installing interceptor drains at much closer spacings.

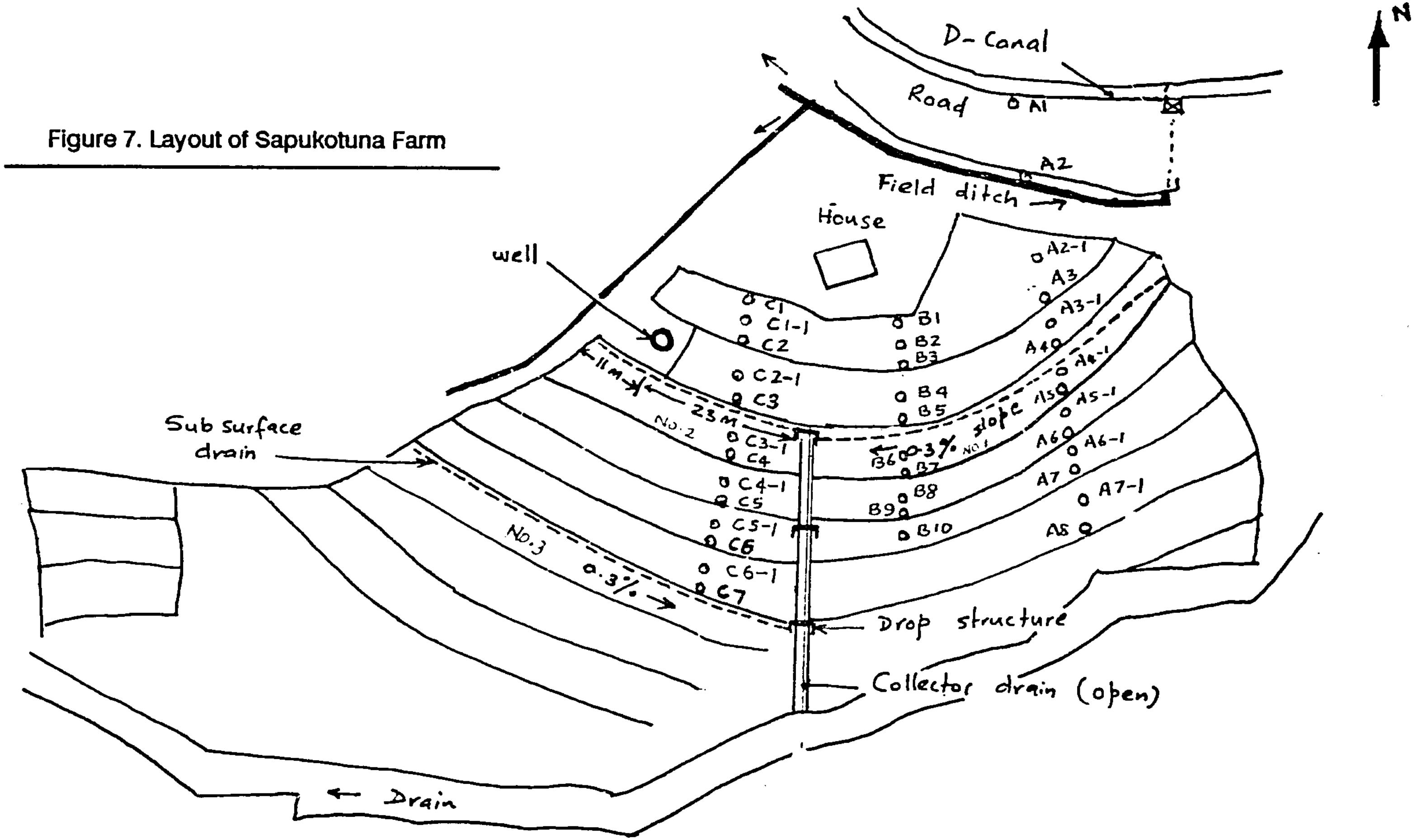


Figure 7. Layout of Sapukotuna Farm

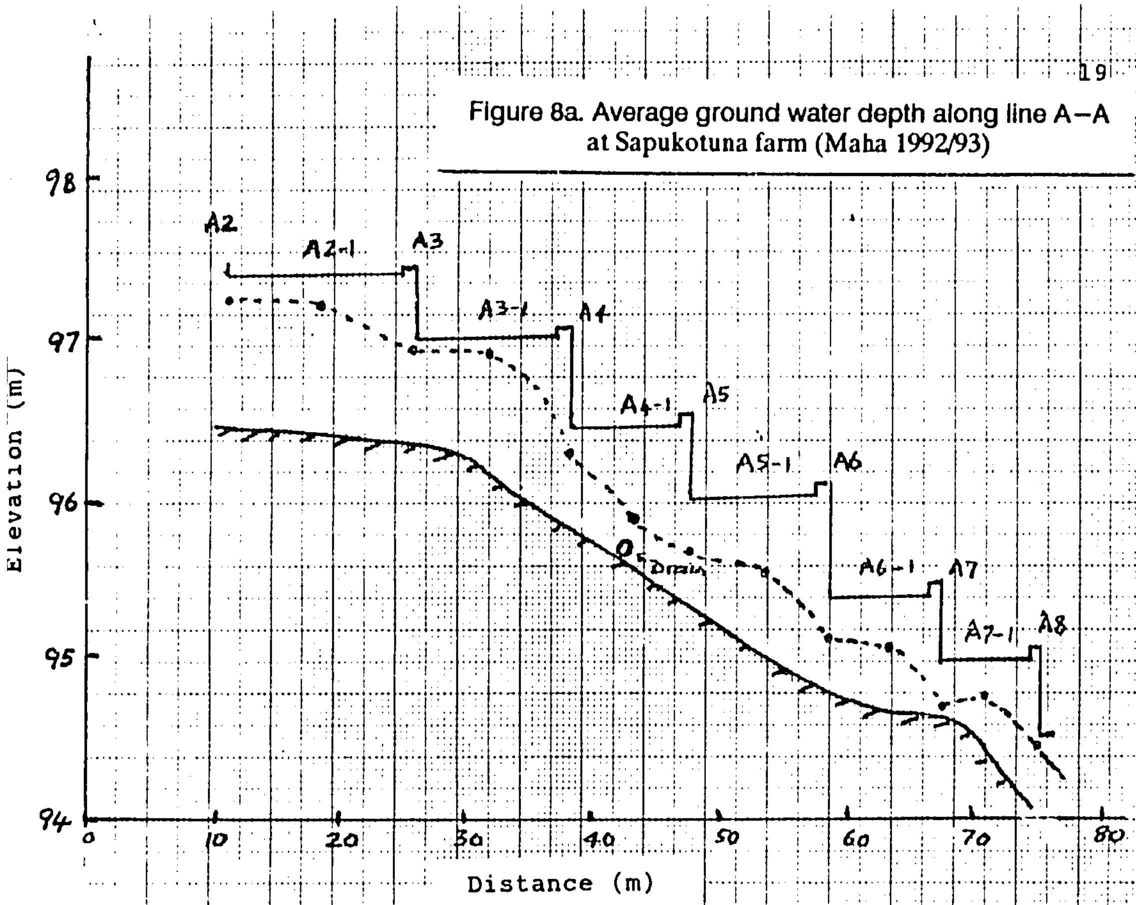


Figure 8a. Average ground water depth along line A–A at Sapukotuna farm (Maha 1992/93)

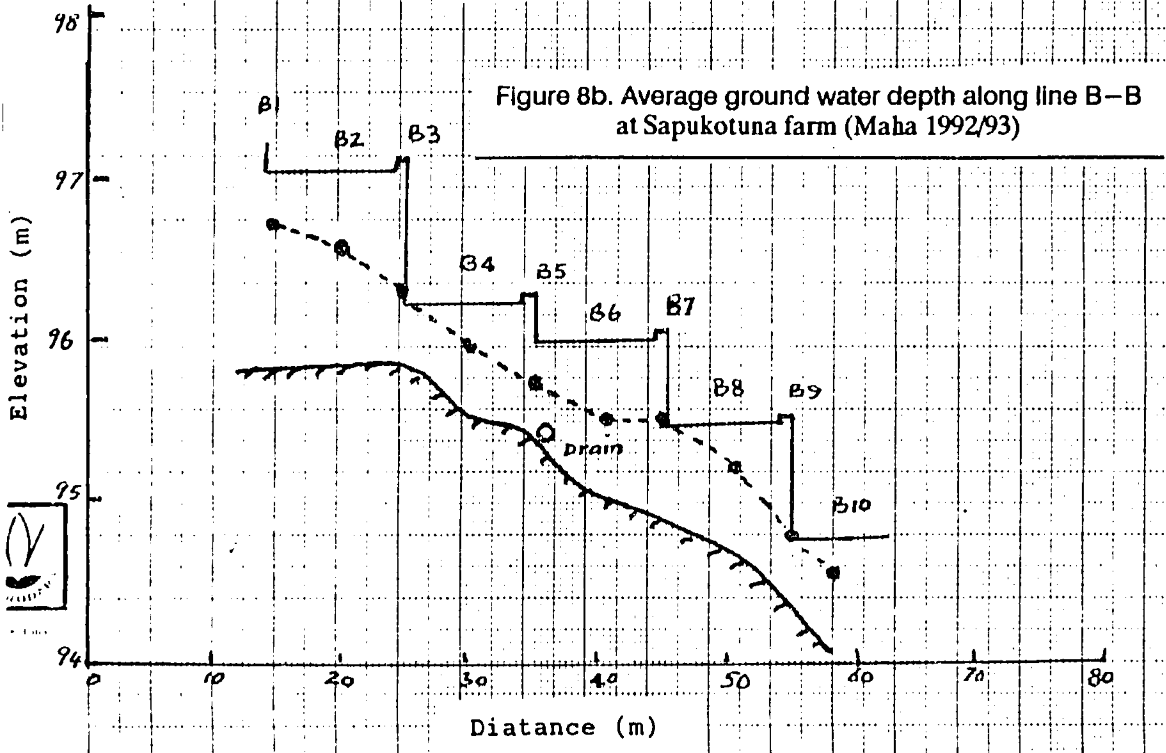


Figure 8b. Average ground water depth along line B–B at Sapukotuna farm (Maha 1992/93)

Figure 8c. Average ground water depth along line C–C at Sapukotuna farm (Maha 1992/93)

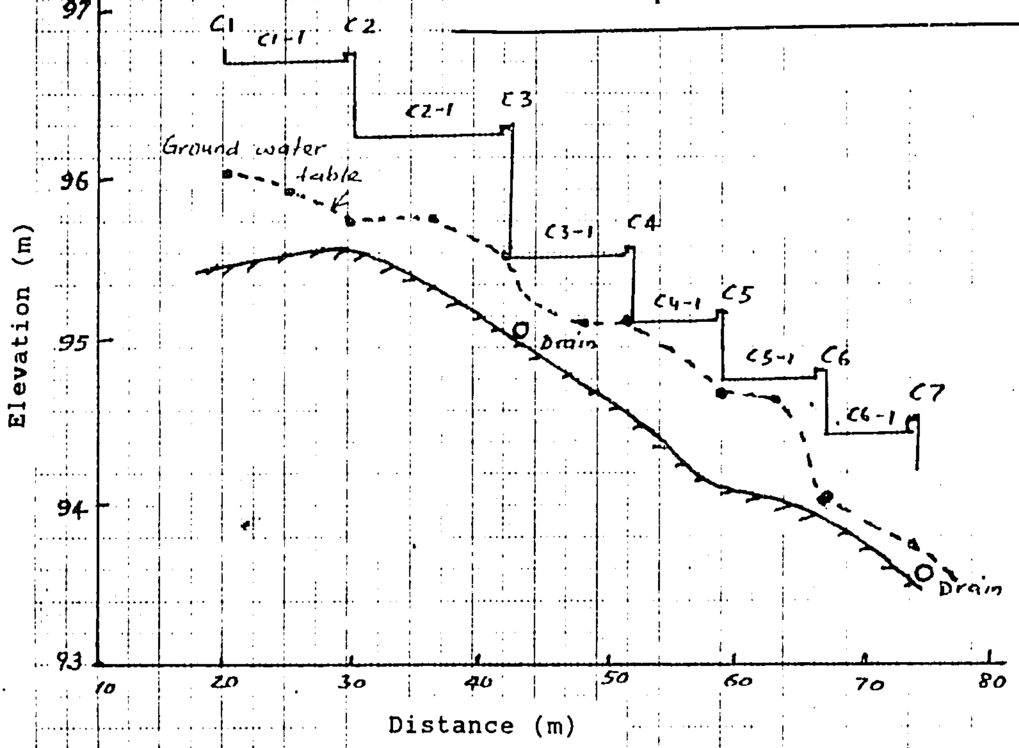
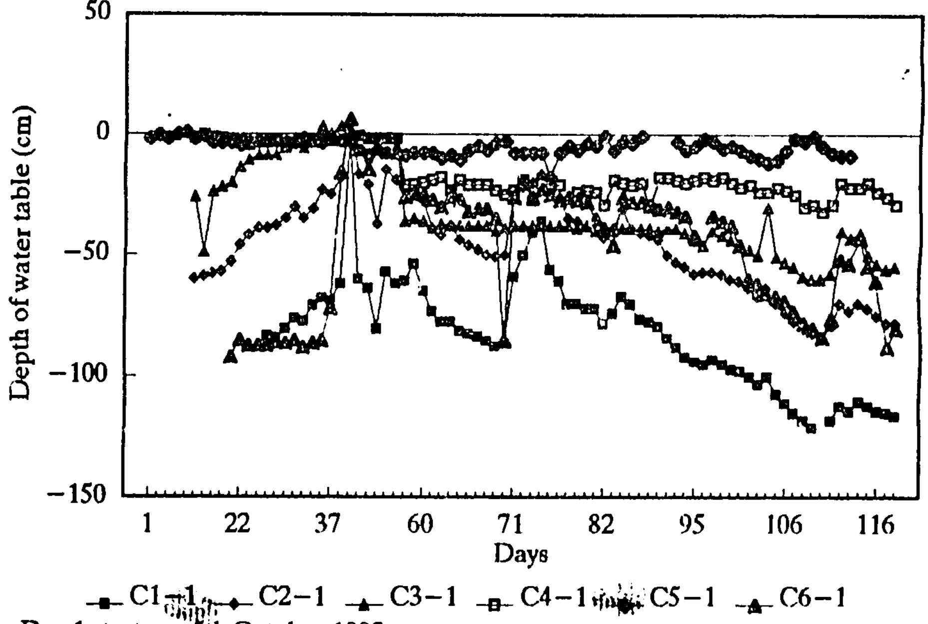


Figure 9. Depth of water table at Sapukotuna farm (Maha 1992/93) along line C–C



Day 1 starts on 5th October 1992

It would have been possible to reduce the water table level in the bottom terraces if the main drain was cleared. The reluctance of the farmer in land smoothing and deepening and clearing the main drain was also partly responsible for poor drainage situation in the farm.

The daily variation of ground water table along the line C-C is given in Figure 9. comparison of the water table behaviour and the rainfall during this period shows that the response of the water table to the rainfall during Maha season was negligible. It was the canal seepage which determined the behaviour of the water table. The heavy seepage was the main cause of drainage problem. This will also prevents the OFC cultivation even during the Yala season.

CONCLUSIONS

The water logging problem could not be solved satisfactorily at Sapukotuna farm as a results of following reasons.

- Heavy seepage from the unlined D-canal,
- Deep cuts in preparing the level terraces in a land with 8-9% slope,
- Poor land smoothing,
- Uncleared main drain, and
- in adequacy of three interceptor drains.

RECOMMENDATIONS

The Sapukotuna farm is an ideal example where problems were created as a result of unplanned land development, on-farm water management and agricultural activities. This land should not have allocated for the cultivation of annual crops in the first place due to its steep slope and the location of the unlined D-canal in pervious soils. The reduction of the thickness of soil restricted the water flow towards the drain thus causing the stagnation of water at the site.

Deep cuts in preparing the level beds is the main reason for water logging among the other reasons. The recommended depth of cut in land development in Mahaweli Systems is 10 cm and should not exceed 20 cm under any circumstance. This recommendation is given for lands upto about 5% slope. At Sapukotuna farm, soils were removed up to 1 m using heavy machinery thus destroying the agricultural potential of the land. The land development and the laying out of irrigation and drainage facilities were done haphazardly.

It is recommended to review the procedure of land alienation in large blocks to the commercial farmers. A potentially good agricultural land can be destroyed beyond repair due to poor land development including laying out of irrigation and drainage net work. farm roads, culverts, buildings etc. Farm planning in a bigger scale is a professional job. Most of the commercial farmers in Mahaweli System B do not possess such knowledge and the development of the farm is given to a heavy machinery driver with no knowledge of agriculture or irrigation.

Therefore, it should be made mandatory for any potential commercial farmer to submit a detailed development plan, indicating farm rods, direction of terraces, slopes, irrigation and drainage layout with structures, location of buildings, etc. Along with the financial proposal, this development plan should be submitted to the authorities for approval. The Mahaweli Authority should reject any proposals which does not have a sound technical development plan for the intended farm. During the development stage, the officials from the Mahaweli Authority could monitor the progress.

It is strongly recommended to implemented a procedure suggested above as early as possible in order to prevent the destruction of valuable land and water resources in Mahaweli Systems. The cost of rectifying the mistakes of unplanned large farms will cost many times more than what could have spent at the beginning for proper development.

The above recommendation may have gone beyond the terms of reference of the consultant. However, the drainage problems in the Sapukotuna farm could have prevented to a greater extent if the land was developed in a much more sensible manner. Therefore, it seems relevant that the recommendation leading to a proper planning and development of a farm is a key to the reduction of drainage problems.

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Annex 1.

Lecture 4. DETERMINATION OF DRAINAGE SPACING

1. Introduction

The factors which influence the height of the water table are:

- precipitation and other sources of recharge
- evaporation and other sources of discharge
- soil properties
- depth and spacing of the drains
- cross-sectional area of the drains
- water level in the drains.

The above factors are interrelated by drainage equations, based on two assumptions, viz.:

- two-dimensional flow, i.e. the flow is identical in any cross-section perpendicular to the drains;

- a uniform distribution of the recharge over the area between the drains;

Most of the equations discussed in this chapter are moreover based on the Dupuit-Forchheimer assumptions. They are;

- flow in the saturated zone is horizontal

- Potential gradient is = water table slope

- no surface of seepage at the vertical exit boundary.

Therefore, the equation has to be considered as approximate solution only. Such approximate solution, however, is generally accepted as having such a high degree of accuracy that its application in practice is completely justified.

2 Steady state drainage equations

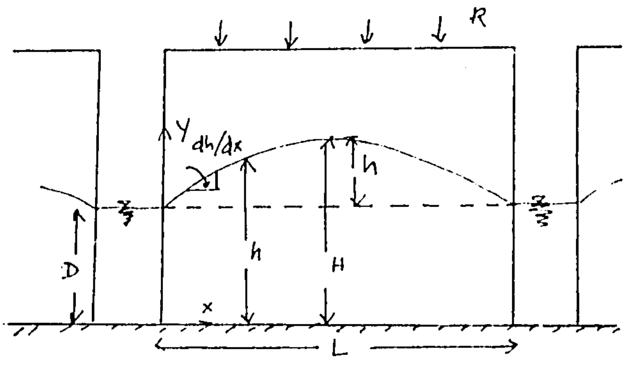

Figure 1. Horizontal flow to ditches reaching an impervious floor

Let us consider the flow through a vertical plane at a distance 'x' from the left ditch. All the water entering the soil to the right of this plane must pass through it on its way to the ditch. If 'R' is recharge per unit area of the soil surface per unit time, then the flow per unit time through the considered plane is;

$$Q_I = R\ (L/2 - X) \quad \ldots\ldots \ (1)$$

From Darcy's law;

$$Q_I = K.h.\ dh/dx \quad \ldots\ldots \ (2)$$

Since the flow-in of the two cases must be equal, we may equate the right side of the two equations.

Hence,

$$K.h.dh/dx = R\ (L/2 - X) \quad \ldots\ldots\ldots \ (3)$$

Multiplying both sides of this equation by 'dx' gives;

$$K.h.dh = R\ (L/2 - X)dx \quad \ldots\ldots\ldots\ldots \ (4)$$

which is an ordinary differential equation and can be integrated. The limits of integration are;

$X = 0$, $h = D$
$X = L/2$, $h = H$

So that we may write;

$$K \int_{h=D}^{h=H} h.dh = R \int_{X=0}^{X=L/2} (L/2 - X)\ dx \quad \ldots\ldots\ldots \ (5)$$

by integration;

$$K/2\ (H^2 - D^2) = R.L^2/4 - R.L^2/8 \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (6)$$

$$R = \frac{4k(H^2 - D^2)}{L^2} = q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (7)$$

where,

R = recharge rate per unit surface area (m/day)
q = drain discharge rate per unit surface area (m/day)
K = hydraulic conductivity of the soil (m/day)
H = height above the impervious floor of the groundwater table midway between two drains (m)
D = height above the impervious floor of the water level in the drains = thickness of aquifer below drain level (m)
L = drain spacing (m)

Equation 7 may be rewritten as

$$q = \frac{4K(H+D)(H-D)}{L^2} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

Setting (Figure 1) h = H-D and H+D = 2D+h, where h is the water table height above drain level at midpoint, i.e.the hydraulic head for subsurface flow into drains, Equation 8 then changes into

$$q = \frac{4K(2D+h)h}{L^2} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

or,

$$q = \frac{8KDh}{L^2} + \frac{4Kh^2}{L} \quad \ldots\ldots\ldots\ldots (10)$$

When there is hardly any water in the drain, i.e. setting D = 0 gives;

$$q = \frac{4kh^2}{L^2} \quad \ldots\ldots\ldots\ldots\ldots (11)$$

Equation 11 apparently represents the horizontal flow above drain level. If D is large compared with h, the second term in the numerator of the right hand side of Eq. 5 can be neglected against the first term, giving,

$$q = \frac{8kDh}{L^2} \quad \ldots\ldots\ldots\ldots\ldots (12)$$

which represents the flow below the drain level.

The above considerations permit the conception of a two-layered soil with interface at drain level.Accordingly Eq.5 may be rewritten as;

$$q = \frac{8K_aDh}{L^2} + \frac{4K_bh^2}{L^2} \quad \ldots\ldots\ldots\ldots (13)$$

where

K_b = hydraulic conductivity of the layer above drain level (m/day)

K_a = hydraulic conductivity of the layer blow drain level (m/day)

Due to the assumptions made in deriving the equation, its use should be limited to the following conditions:

*

Where ground-water flow is known to be largely in horizontal direction. Examples of this are stratified soils with relatively permeable layers acting as horizontal aquifers.

* Where soil and subsoil materials are underline by a barrier at relatively shallow depths (twice the depth of the drain or less) which restricts vertical flow and forces the ground water to flow horizontally toward the drain.

* Where open ditches are used, or where drains with sand and gravel filters or porous trench backfill materials are used. These are conditions where there is a minimum of restriction to flow into the drain itself and where convergence of flow at the drain is slight.

Example 1:

The following example is given to illustrate the use of this equation when variable (h) does not exceed the value of variable (D).

* Parallel drains are to be installed at a depth of 1.5 m.

* Subsoil boring indicate an impervious barrier at a depth of 2 m below the ground surface.

* The minimum depth of water table desired, after drainage, is 0.5 m.

* The average hydraulic conductivity of the subsurface materials is 1.2 m/d.

* The applicable drainage coefficient for the area is 0.07 m/d.

Substituting to the equation,

$$L^2 = \frac{8KDh + 4Kh^2}{q} \quad \dots\dots\dots\dots (10)$$

$$= \frac{8\ (1.2)(0.5)(0.5) + 4\ (1.2)(0.5)^2}{0.07}$$

$$= 51.42$$

$$L = 7.5 \text{ m.}$$

In actual practice this would be adjusted to confirm with field dimensions. The precision of the data is such that an adjustment of 5 percent in the spacing is considered permissible.

If the ditches do not reach the impervious floor, the flow lines will not be parallel and horizontal but will converge towards the drain (radial flow). In this region the flow system cannot be simplified to a flow field with parallel and horizontal streamlines without introducing large errors.

However, the equation given above is adequate to determine drainage spacings in irrigation systems in Sri Lanka since soil depth is shallow and hence satisfy the assumptions laid out in deriving the equation.