WATER USE PERFORMANCE

Management Innovation and Performance of Irrigated agriculture
A case Study of Muda Irrigation Project

by

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1. INTRODUCTION

This study is a part of the IIMI-MADA Collaborative Project under IIMI's program "Assessing and Improving Performance of Irrigated Agriculture" (AIPIA). Muda Agriculture Development Authority (MADA) is the management organization of the Muda Irrigation Project, Malaysia established in 1970. IIMI is one of international agriculture research centers under CGIAR established in 1984 as a convening center for water resources.

The Muda area encompasses 97,000 ha of rice fields and 60,000 farm households. It produces 800,000 tons of unhulled rice annually. The rice production ascribes its water resources to rainfall, dam storage and uncontrolled river flow. Recent steady decline of annual rainfall stimulates MADA and Muda farmers to develop management innovation to facilitate adequacy of water use. The history of the management interventions implemented by MADA and Muda farmers could be delineated as follows.

1966 Construction of irrigation and drainage systems (so called Muda I Project) launched.
1970 Rice double cropping started.
Plowing has been mechanized.
1977 Tertiary development project (so called Muda II Project) launched.
1978 Fertilizer subsidy started.
1980 Rice price subsidy started.
1984 Commission of tertiary systems commenced.
1985 Mechanized harvesting expanded to the whole Muda area.
1986 Direct sowing area expanded to 50 % of the area.
Formulation of the last day of irrigation supply started.
1988 Computerization of performance data was initiated.
1989 The data feedback system fully functioned.
1992 Irrigation scheduling based on dry sowing was adopted.

Water shortage has been the most significant constraint to proper performance of the Muda agriculture since 1975 when the double clopping expanded into the whole Muda Area. Neverthless, MADA's efforts to implement series of interventions have resulted in efficient use of local water resources and maintaining stable and high cropping intensity of 195 %.

This paper propose a method of assessing water use performance and verify it in a case study of the Muda Irrigation Project. And it further focuses impacts of individual intervention on water use performance pertaining to water saving and its cost in the Muda Irrigation Project. Water use performance is one of 4 major performances in AIPIA; i.e. water use performance, water delivery performance, agricultural performance and economic performance.

2. WATER USE PERFORMANCE AND MANAGEMENT INTERVENTIONS

Efficient use of local water resources should be one of irrigation managers' most interests in their business especially in projects with serious water shortage problem like the Muda area. In order to meet with farmers' water demands, irrigation managers will make every effort to implement effective interventions which impacts will be assessed by change in water demands, water supply and cost of water developed.

Water resources

In the Muda area, available water resources are about 4500 mm/97,000ha consisted of dam inflow, rainfall, uncontrolled river flow and drainage water for recycling (refer Table 1 and Fig. 3). Ground water, however, is not available without potential aquifer in its very heavy clayey soil layers.

TABLE 1. WATER RESOURCES AND UTILIZATION (Unit: mm)

Category	Resources	Utilization	%
Dam inflow	800/790	570/790	71/81
Rainfall in the command area	1990/1870	1560/1170	78/63
Uncontrolled river flow	620/780	190/80	31/10
Drainage water for recycling use	1140/1070	0/140	0/13
Underground water	0/0	0/0	-
Total	4550/4510	2320/2030	51/45

Note: Average during (1980 to 1984) / (1988 to 1992)
%: Utilization ratio over resources in each category
Data source: MADA

Water use performance

Irrigation managers who are facing to water shortage problem should be interested in quantity of available water resources and actually utilized water. After irrigation managers make some countermeasures to improve utilization of local water resources, they will assess impacts of the countermeasures by change in water volume utilized and its ratio over the available water resources.

Quantity of water resources are also variable by management interventions. Dam inflow will be increased by construction of reservoirs although it decreases uncontrolled river flow instead. Available rainfall for a season can be changeable by shifting cropping schedule. Drainage water is also influenced by cropping methods, drainage improvement, operation of drainage systems, etc.

Accordingly, the following 4 items can be proposed as factors of the water use performance.

(1) Quantity of water resources
(2) Quantity of actually used water
(3) Ratio of water used
(4) Cost of water produced or saved by a management intervention

Management intervention

Management interventions to improve of water use performance are investment for irrigation managers or farmers who aim to overcome water shortage and make more profit. Amount of investment will be largely influenced by implementation level of interventions. Irrigation managers will have series of repetition to examine economic return for each combination of interventions which maximizes water use and profit. Cost efficiency of an intervention is usual basis of irrigation managers to make decision of the intervention to be implemented. Management interventions relative to water resources are hypothesized as follows.

Effective rainfall

- Performance oriented water management supported by data feedback system
- Reinforcement of dike of rice fields
- Maintenance of field water depth adequate to reserve rainfall

Uncontrolled river flow

- Construction of reservoirs

Drainage water

- Construction of recycling pump stations
- Control of water level in tertiary drains
- Cropping methods

Total water supply

- Tertiary development
- Shortening of irrigation period
- Planting short term varieties
- Formulation of rigid water cut date
- Shift of cropping methods
- Organization of farmers into farm working groups

In the 3rd column of Table 1 is comparison of change in water utilization between two periods, i.e. from 1980 to 1984 and from 1988 to 1992. After 1984, a number of interventions have been implemented by 1992; e.g. mechanized harvesting by large sized combine harvester extended into the whole Muda area, direct sowing became dominant taking place of transplanting, last date of irrigation supply was formulated, performance oriented water management system was established supported by the data feedback system, dry sowing was introduced into official cropping scheduling, and so on. These changes would have influenced water use performances of the area.

Assessment indicator

In this paper, the following three kinds of assessment indicators are defined for convenience to study linkage between water use performances and management interventions.

Performance indicator:	Extent of water use performance induced by a management intervention
Determinant indicator:	Implementation level of a management intervention
Impact indicator:	Extent of intermediate performance induced by a management intervention

Taking an example in tertiary canal construction as a management intervention, canal density will be a determinant indicator. Enhanced canal density will influence to water use performance. Firstly. field water depth distribution will become even after plot-to-plot water conveyance is taken place by independent water distribution to each lot through tertiary canal and distribution loss is reduced. Secondly, total water supply will decrease as a result of low distribution loss. The total water supply can be a performance indicator and water distribution can be an impact indicator.

Management interventions and concerned indicators can be proposed as follows in regard to water use performance.

Data feedback system

Determinant indicator:	Time lag of data feedback
Performance indicator:	Ratio of effective rainfall
	Seasonal irrigation supply
	Seasonal dam release

Construction reservoirs

Determinant indicator:	Total dam capacity
Performance indicator:	Seasonal dam release
Impact indicator:	Seasonal dam inflow
	Seasonal uncontrolled river flow

Construction of recycling pump stations

Determinant indicator:	Total pump capacity
	Quantity of drainage water available
Performance indicator:	Actual quantity of recycled water
Impact indicator:	Pumping time

Formulation of rigid water cut date

Determinant indicator:	Date of water cut
Performance indicator:	Seasonal irrigation supply
Impact indicator:	Irrigation period
	Last date of the season

Control of cropping methods

Determinant indicator:	Proportion of cropping methods
Performance indicator:	Total water supply
Impact indicator:	Water requirement
	Seasonal total rainfall and effective rainfall
	Seasonal dam release

Tertiary development under transplanting

Determinant indicator:	Ratio of lots with direct access to canal
Performance indicator:	Irrigation supply during presaturation period
Impact indicator:	Duration of presaturation period

Tertiary development under direct sowing

Determinant indicator:	Ratio of lots with direct access to canal
Performance indicator:	Irrigation supply
Impact indicator:	Field water depth distribution

Water use structure

Impacts of a management intervention are directly reflected on concerned indicators which give indirect impacts to other indicators. Accordingly, these indicators organize a linkage network which can be utilized to assess and simulate impacts of interventions (refer Figure 3).

3. SHORTENING OF IRRIGATION PERIOD

Duration of irrigation period is an important factor of water use. Needless to say that longer period requires more water. Shortened irrigation period, accordingly, directly influence to seasonal quantity of irrigation/water supply. MADA and Muda farmers have implemented series of interventions which gave impact on duration of the irrigation period.The followings were identified as management interventions relevant to irrigation period.

Shift of cropping method

In early 1980s, labor shortage problem encourages Muda farmers to practice wet sowing. Then, in late 1980s, chronic decrease in rainfall aggravated water supply situation in the 1st season and stimulated farmers to adopt dry sowing to the 1st season. These shifts largely inclined water requirements.

Formulation of rigid water cut date

Since 1986, MADA set up official water cut date and announced it to farmers prior to a season. It was effective to press early commencement of cropping activities by farmers and to eliminate prolonged cropping schedule.

Implementation of tertiary development

Tertiary development should be effective to shorten irrigation period of transplanting method in the Muda area in which canal systems are arranged approximately at an interval of 1 mile (1.6 km) resulting in difficulty in separated water supply between main fields and nursery beds and prolonged flooding period in main fields as well.

Although it was not yet certified by field survey, tertiary development will have conflicting impacts on water use performance. It will rationalize water distribution leading to decrease in water distribution loss. On the other hand, it will motivate farmers to conduct elaborate field water management leading to increase in management loss.

Short term varieties

Planting short term varieties is a measure to shorten irrigation period if adequate varieties are released. Although 115 day variety with considerably high yield has been released, Muda farmers' favorite is a 130 day variety which is being planted in 75 % of the Muda area.

TABLE 2. BASIC DATA OF MUDA'S CROPPING METHODS

Item	Trans-planting	Wet sowing	Dry sowing
Duration of irrigation period in main field based on 120 day varieties (days)			
1st season	125	135	90
2nd season	115	120	-
Seasonal water requirement (mm)			
1st season	1320	1490	960
2nd season	850	1010	-
Standard seasonal yield (ton/ha)			
1st season	4.0	3.5	3.0
2nd season	4.5	4.5	-
Production cost (Rm/ha/season)	1000	760	610
Average gross profit (Rm/ha/season)			
1st season	2840	2480	2130
2nd season	3190	3190	
Average net income (Rm/ha/season)			
1st season	1840	1720	1520
2nd season	2190	2430	
Water profitability (Rm/1000cum)			
1st season	139	115	158
2nd season	258	241	-

Note: Dry sowing is not applicable to the 2nd season
Gross profit = Yield x Rice price (Rm.709.8/ton)
Net income = Gross profit - Production cost
Water profitability = Net income / Water requirement (in total water supply basis)

3-1. SHIFT OF CROPPING METHODS

MADA and Muda farmers have 3 alternative cropping methods; i.e. transplanting, wet sowing and dry sowing which water requirement largely varies. Their basic performance data are as shown in Table 2. summarizing the previous field tests and performance analyses. Their water requirement varies each other due to different irrigation period and presaturation requirement (refer Fig. 1).

There is no available date to investigate individual water profitability per irrigation supply nor dam release because of technical obstacle to itemize each supply element to each cropping method. The overall water profitability, however, can be found as in Table 9.

Recently, composition of cropping methods is 0 : 3 : 7 in the 1st season and 1 : 9 : 0 in the 2nd season for transplanting, wet sowing and dry sowing respectively.

Transplanting method

Transplanting method is a traditional method. Its production is high and stable but costly because of high labor consumption for pulling, transporting and planting seedlings. With boost of agricultural wage due to recent rapid economic growth of the country, its production cost rose sharply and it has been taken its superiority in the cropping methods by direct sowing since the late 1980's. Nowadays, transplanting is adopted mostly in ill-drained areas with deep water which field condition dose not suit to direct sowing.

Water requirement of transplanting varies between sub-systems without tertiary development (so called Muda I system) and those with tertiary development (so called Muda II system).

In a Muda I system, irrigation period in main fields is extended to nursery rising period because of difficulty in separated water supply between main fields and nursery beds due to lack of in-field water distribution system.

Wet sowing

Wet sowing method was developed by MADA and farmers to overcome labor shortage problem of the transplanting method. This method requires presaturation, puddling and leveling of field surface and surface water drainage before broadcasting pre-germinated seeds. Growth period in main fields is prolonged about 10 days in comparison with transplanting method whose seedlings are raised in nursery beds for about 25 days. Those result in the highest water demand among the three methods.

In wet sowing method, seeds germinate on once puddled and then drained field surface. Consequently, planting depth becomes shallow and paddy plants are not tolerant to lodging caused by heavy rain and strong wind in the rainy season from middle of August to October leading to bulky harvesting losses.

Wet sowing is the dominant method in the 2nd season covering more than 80 % of the area in the recent years.

Dry sowing

Dry sowing method was developed by farmers in order to cope with water shortage problem. In this method, seeds are plowed into soil prior to rainy season. After rainfall stimulates germination of the seeds and the seedlings are established throughout a region, water supply starts. This method is characterized as low water demand due to short irrigation period and lack of presaturation supply, and low yield due to severe intrusion of weeds. Low yield also depends on significant harvesting loss under mechanized harvesting with large sized combine harvester due to uneven maturing period within a lot.

In the recent years, the dry sowing method covers about 70 % of the area in the 1st season. This is not applicable to the 2nd season because of inadequate weather and field conditions for the dry sowing.

Impacts of change in cropping method on water use performance

Impacts of change in cropping methods on water use performance can be summarized as shown in Table 3. Dry sowing economize water consumption reducing water requirement by 30 to 35 % despite benefit reduction by 20 to 30 %. Wet sowing is profitable both in the 1st and 2nd season though it requires high water consumption.

TABLE 3. COST OF WATER SAVED BY SHIFT OF CROPPING METHODS

Change	Water saving (mm/ha)	Cost (Rm/ha)	Water cost (rm/1000cum)
1st season			
TR to WS (Muda I)	-70	-120	-17
TR to DS (Muda I)	460	320	70
WS to DS (Muda I)	530	200	38
TR to WS (Muda II)	-170	-120	-71
TR to DS (Muda II)	360	320	89
WS to DS (Muda II)	530	200	38
2nd season			
TR to WS (Muda I)	-110	-240	-220
TR to WS (Muda II)	-160	-240	-150

Legend: TR: Transplanting
WS: Wet sowing
DS: Dry sowing

3-2. FORMULATION OF RIGID WATER CUT DATE

Formulation of rigid water cut date was one of MADA's interventions to save water consumption increased by prolonged cropping season. Since 1984, MADA formulates the last date of water supply and announces it to farmers prior to the season. It presses farmers to conduct early commencement of farm activities to avoid yield reduction due to draught. Pumping water from drainage canals into farm lots using farmers' potable pumps will be another choice to eliminate from the yield reduction.

Impact of rigid water cut date

The last date of harvesting of the 2nd season was 433th day after i January in average from 1980 to 1983 when water cut date was not formulated. On the other hand, it was made earlier by 32 days to 401th day during 1984 to 1993 through shortening of transition period from 1st to 2nd season. Accordingly, 32 days is regarded as an impact of the rigid water cut day.

When daily water requirement in 2nd season is estimated at 7.25 mm/day (refer Annex 2), its impact on water saving will be 225 MCM for the whole Muda area of 97,000ha or 2,320 cum/ha. (cum: cubic meter)

Cost of water saved by rigid water cut date

Harvesting period comes about 1 month after flowering. Usually farmers start drying field 2 weeks before harvesting in order to reinforce soil bearing capacity sufficient to bear large sized combine harvester. As 10 cm water depth can last about for 2 weeks, water cut after flowering will barely influence the yield.

MADA's database presents performance of the rigid water cut date during 1986 to 1992 that flowering status was 88 % at the initial water cut date of 25 January and 96 % at actual water cut date of 4 February although the last flowering date (99%) was 15 February. Though the rigid water cut date was actually not rigidly observed, it was enough to give farmers psychologic menace to press early farming activities as mentioned earlier. But after 1991, it seems that there was almost no time lag between the official and actual water cut day and that the rigid water cut day came to stay among farmers.

TABLE 4. DATE OF WATER CUT AND FLOWERING STATUS

Year	Date 1 (%)	Date 2 (%)	Date 3 (99%)
1986	31/01 (87)	01/02 (88)	27/02
1987	07/01 (59)	31/01 (97)	04/02
1988	19/01 (93)	01/02 (96)	24/02
1989	24/01 (92)	16/02 (99)	13/02
1990	28/01 (90)	05/02 (95)	23/02
1991	31/01 (99)	01/02 (99)	04/02
1992	02/02 (98)	03/02 (98)	09/02

Average 25/01 - 88 04/02 - 96 15/02

Note: Date 1: Official water cut date (day/month)
Date 2: Actual water cut date (day/month)
Date 3: Last date of flowering (day/month)
%: Flowering status

If the initial water cut day was rigidly implemented, 12 % of the area had to pump up drainage water by their own potable pumps with diameter of 100 mm and capacity of 1 cum/min for 21 days from 25 January to 15

February. Water volume to be pumped up during the period amounts to 18 MCM provided that daily water consumption is 7.25 mm/day. The total operation time of pumping 18 MCM will be 300,000 hours by 100 mm pump which is the most common potable pump among Muda farmers.

Cost estimation is listed below.

Diesel consumption of pump (potable diesel pump): 8 liter/1000cum
Price of diesel: Rm.0.66 /l
Unit cost of pumping: 8 liter/1000cum x Rm.0.66/liter = Rm.5.28/1000cum
Total cost for 18 MCM: Rm.95,040
Labor input: 1 man-hour per 8 hours operation
Wage: Rm.14 per 8 man-hour
Labor cost: 300,000 / 8 x Rm.14/8 = Rm.65,625
Total cost for 18 MCM: Rm.160,665
Cost of water pumped: Rm.160,665/225MCMC = 0.71/1000cum

3-3. TERTIARY DEVELOPMENT IN RELATION WITH TRANSPLANTING METHOD

Impact of tertiary canal will be distinct in transplanting method practiced in Muda I blocks. In those blocks, terminal canal and road systems are arranged at a 1 mile interval in standard. Farmers use about 40 day old seedlings to meet deep water field conditions imposed by poorly developed field infrastructure although MADA recommends 25 day old seedlings. Weight of seedlings amounts to 1.5 tons per hectare and it dictated heavy works of in-field transportation to farmers. In order to avoid this, farmers usually prepare their nursery beds within their main fields. As a result, main fields are submerged throughout seedlings rising period of one and half to two months. Despite 30 days of presaturation period for land preparation, the main fields have to be flooded for 55 days of nursery raising period including 15 days of nursery bed preparation period. Accordingly, impact of the tertiary development will be shortening of presaturation period by 25 days per season.

Impact of tertiary development

Tertiary development will offer farmers frequent chances of manipulating field water depth resulting in increased water consumption. There should be an impact on efficiency of water delivery leading to reduction in water distribution. Because this hypothesis has not been tested, impact of tertiary development is limited in only impact on shortened presaturation period in main fields under transplanting method in this paper.

Water volume saved by shortening of presaturation period

> Shortened period: 25 days for both of 1st and 2nd season
> Water requirement during presaturation period:
> 10 mm/day in 1st season
> 5 mm/day in 2nd season
> Water volume to be saved: 3,750 cum/ha/year

Cost of water saved by tertiary development (Data source: MADA, 1988, Muda II project, Project Completion Report. Refer Annex 3.)

Capital cost:	Rm.9,373/ha (1993 price)
Official discount rate:	6%
Annual cost for the capital cost:	Rm.562/ha (9373 x 6%)
O&M cost of tertiary system:	Rm.113/ha
Annual cost of tertiary system:	Rm.674/ha (562 + 113)
Yield increase:	0.2 ton/ha/year
Labor saving:	27.7 man-hour/ha
Profit by labor saving:	Rm.48.5/ha = Rm.12/ton
Production cost:	Rm.223/ton in 1993 price based on 1990 production
Producer's price:	Rm.709.8/ton
Net unit profit:	Rm.499/ton (709.8 -223 +12)
Gross profit:	Rm.100/ha (0.2 x 499)
Total annual cost:	Rm.574/ha (674 - 100)
Water cost:	Rm.153/1000cum (574/3,750)

3-4. SHORT TERM VARIETY

Planting short term varieties is directly reflected on irrigation period. Shortening irrigation period by 5 days is equivalent to annual water saving of 794cum/ha; i.e. 431cum/ha in the 1st season and 363cum/ha for the 2nd season assuming that daily water demands is 8.625 mm/day for the 1st season and 7.25 mm/day for the 2nd season (refer ANNEX 2).

Usually rice varieties are selected based on not only yield but also quality of grain, taste, resistance to diseases and pests, tolerance to lodging and so on. In this paper, however, cost of water saved by planting short term varieties is tentatively estimated by change in potential yields of groups with same growth duration. Yield largely varies among varieties within the same group. Still yield should be one of the most important elements for farmers to select varieties.

According to experiment by MARDI, Seberang Perai, the upper yield in each group confines at 5.8 ton/ha for 140 day group, 6.3 ton/ha for 135 day group, 7.1 ton/ha for 125 day group and 6.2 ton/ha for 115 day group. The most popular variety in the present Muda area is MR 48 which belongs to 130 day group with potential yield of 6.8 ton/ha (refer Fig. 2). Based on 130 day variety, impact of short term varieties on water saving and cost of water is presented as follows.

125 day variety is effective to shorten irrigation period by 5 days and to save 794 cubic meters of water per hectare. Since its potential yield higher than that of 130 day varieties by 0.3 t/ha/season, it makes a profit of Rm.270/ha/year. 120 day variety is in similar yield level with 130 day variety.

TABLE 5. IMPACT OF SHORT TERM VARIETY BASED ON 130 DAY VARIETY

Growing period	125 day	120 day	115 day
Water to be saved (cum/ha/year)	794	1588	2382
Increase in yield (t/ha/year)	0.6	0	-1.2
Decrease in profit (Rm/ha/year)	-270	0	539
Cost of water (Rm/1000cum)	-340	0	226

Note: Profit (Rm/ton) = Rice price - Production cost
Rice price: Rm.709.80/ton
Production cost: Rm.260.23/ton (Refer Annex 4)

Despite of high water saving effect and potential yield, 125 and 120 day varieties are not acceptable by Muda farmers. there would be some reasons such as susceptibility to diseases, grain quality, taste, etc.

4. UTILIZATION OF UNUSED WATER RESOURCES

The main water resources in the Muda area are rainfall, dam inflow, uncontrolled river flow and drainage water for recycling. Approximately, 4.5 billion cubic meter of water resources were identified, half of which are utilized for the rice production. Rainfall and dam inflow are efficiently utilized but uncontrolled river flow and drainage water are still underdeveloped (refer Table 1 and Figure 3).

Ineffective rainfall and outflow to the sea will be out of re-utilize in the Muda area because of its extremely flat topography with no adequate site for construction of tanks. MADA's previous interventions to make efficient use of local water resources were establishment of Data Feedback System (DFS) and installation of recycling pump stations.

4-1. RECYCLING USE OF DRAINAGE WATER

The water resources for recycling will originate from seepage and percolation from rice fields and conveyance loss from canal systems. Use of drainage water is an interest of MADA who is suffering of chronic water shortage problem. Ineffective rainfall could not be used as its timing dose not coincide with that of irrigation demand.

MADA has installed 10 recycling pump stations since 1984. The total pump capacity reached to 8.3 cum/sec in 1986, 16.7 cum/sec in 1989 and 22.4 cum/sec in 1993. The seasonal water volume pumped by those stations amounted to 67 MCM in the 2nd season 1992 and 57 MCM in the 1st season 1993.

Capital cost of recycling station

Electric Submersible Pump (ESP) was adopted by MADA for recycling pump stations because of its tractable operation and easy maintenance although its capital cost is higher than diesel pump station. The unit capital cost per pump capacity (cum/sec) of 5 ESP stations constructed from 1984 to 1987 was as follows in 1993 price (refer Annex 5).

Civil works: Rm.63,000/cum/sec
Equipment: Rm.123,000/cum/sec
Electric wiring: Rm.20,000/cum/sec

The total capital cost of the existing 10 stations with capacity of 22.4 cum/sec will be Rm.4.6m with breakdown into Rm.1.4m for civil works, Rm.2.8m for equipment and 0.4m for wiring.

Annual cost of recycling station

Annual cost of capital cost: Rm.276,000/year

Civil works: Rm.1.4million x 0.06 = Rm.84,000
Assuming official discount rate at 6 %
Equipment: Rm.2.8million x (1.00 - 0.10) / 15 = Rm.168,000
Assuming salvage value at 10 % and durability at 15 years
Electric wiring: Rm.0.4million x 0.06 = Rm.24,000
Annual cost: Rm.276,000

O&M cost: Rm.470,000/year

Unit cost: Rm.4.2/1000cum
Water volume pumped: 112 MCM/year (average during 1987 to 1992)
Annual cost: Rm.470,000/year

Total annual cost: Rm.764,000/year

Cost of water: Rm.6.8/1000cum (Rm.764,000/112 MCM)

4-3. CONSTRUCTION OF DAM

It is estimated that about 85 % of uncontrolled river flow during the irrigation season is annually wasted to the sea (refer Figure 3) although MADA gives uncontrolled flow priority over the dam storage in its irrigation management. The low utilization of river flow may attributed to discrepancy in its timing with water demands. In order to make use of the wasted flow, it is required to construct reservoirs in the upstream of the Headwork which store the excessive flow in reservoirs during flooding period.

Capital cost of a reservoir depends on conditions of construction sites, capacity of reservoir, structure of dams, compensation cost and so on. Because of difficulty to estimate capital cost of a reservoir and its water cost, this paper refers capital cost and water cost of existing Muda and Pedu dams, the main reservoirs of the Muda Irrigation Project.

The capital cost of the hardware facilities in the Muda I project is found at Rm.401million or Rm.4,103/ha with breakdown into Rm.1,460/ha for the reservoirs, Rm.1,279/ha for the main canal system and Rm.1,395/ha for the internal reticular system (refer Table 6).

TABLE 6. CAPITAL COST OF MUDA I PROJECT
(Unit: Rm.million in 1993 price)

Item	Cost
Access road to reservoirs	13.3
Dams and tunnel	107.6
Main canal and headwork	105.9
Control system	3.6
Consultant fees	24.9
Land acquisition	30.2
Internal reticular system	115.5
	401.0

The capital cost of the Muda I Project can be itemized into Rm.142million for the reservoirs, Rm.124million for the main canal and Rm.135million for the internal reticular system. As it is considered that development of wasted uncontrolled river flow into controlled river flow dose not requires expansion of canal capacity, anticipated water cost can be estimated as follows.

Annual cost of the Muda I Project

Capital cost: Rm.8.5 million/year
Rm.142 million x 0.06 (official discount rate)

Cost of water created by reservoirs: Rm.11/1000cum (excluding O&M cost)

Annual dam release: 810 MCM (average of 1988 to 1992)
Cost of water: Rm.8.5m / 810 MCM = Rm.11/1000cum

The above cost excludes O&M cost as data of the O&M cost have not been ready.

4-4. DATA FEEDBACK SYSTEM

MADA's Data Feedback System (DFS) has been established in 1986 and fully functioned since 1989. It is consisted of 25 monitoring stations which monitor dam storage, rainfall and uncontrolled river flow, telemetric system which transmits data from the 25 stations to the MADA HQ, and 27 VHF stations and Local Area Network for data transmission between the MADA HQ, 4 District Offices, 27 Locality Offices and field operators in charge of operation of the irrigation and drainage systems composed of 110 irrigation blocks.

DFS has materialized 1 day time lag between performance monitoring by field operators, transmission of the monitored data to HQ, and daily formulation and direction of target discharge by HQ, and execution of discharge control by field operators based on the target discharge formulated by HQ. DFS was the potential momentum for MADA to establish its existing performance oriented water management system.

MADA's performance indicator for discharge control is field water depth at 550 fixed monitoring points in the 110 irrigation blocks. Discharge at every control structure is formulated as to maintain the lower control depth (LCD) of 10 cm when uncontrolled river flow is available, and to maintain the minimum water depth (MWD) of 5 cm when uncontrolled river flow is insufficient and dam release is required. The standard height of dike in farm lots is 15 cm which is upper control depth (UCD). The water depth between UCD and LCD functions as buffer to catch rainfall and stock excessive irrigation supply. When there is rainfall in the command area, the telemetric system transmits real time rainfall data to HQ. Amount of rainfall is immediately reflected to the dam release and rainfall and dam release for succeeding 2 days, which is arrival time of dam release to fields, are stocked in lots up to UCD. Rainfall and irrigation supply beyond UCD go to ineffective accordingly. Impacts of DFS is not been finalized and the relevant field survey is still under way.

5. WATER USE PERFORMANCE IN THE MUDA AREA

Water use performance achieved in the Muda area will provide irrigation managers and researchers with potent standards of assessment indicators to evaluate performance of other projects. As impacts of interventions are influenced by various endemic factors of each project, similar study should be carried out for each project with notable interventions to standardize inter-project indicators. Then, Irrigation managers could collate performances of their projects with those of comparable projects. Water use performances in the Muda area are quantified as summarized in Table 7. In this connection, the water charge collected from farmers is Rm.37/ha/year irrespective of amount of water used. As total irrigation supply is 721 mm/year (average during 1988 to 1993) or 7,210 cubic meter (cum) per hectare per year, water charge is equivalent to Rm.5/1000cum per irrigation supply.

TABLE 7. IMPACT OF MANAGEMENT INTERVENTION

Intervention	Water saving	Cost of water (Rm/1000 cum)
Rigid water cut date	2,300 cum/ha/season	0.71
Shift of cropping method		
From TR to WS	-900 cum/ha/season	-120
From TR to DS	4,600 cum/ha/season	70
From WS to DS	5,300 cum/ha/season	38
Short term varieties	80 cum/ha/day	Depends
Data feedback system	On data collection	
Recycling pump stations	112 MCM (actual result)	6.8
Reservoir	810 MCM (actual result)	8.5
Tertiary development		
Transplanting method	3,750 cum/ha/year	253
Direct sowing	On data collection	

Note: TR: Transplanting
WS: Wet sowing
DS: Dry sowing
Reservoir: The cost excludes O&M cost.
Water saving: Minus value means increment in water use.
Cost of water: Minus value means profit.

The quantified indicators will conduce to irrigation managers making decisions on management and development of local water resources. They would be advantageous for irrigation managers in the following points.

(1) Provide them with solid comparative standard of water and cost effectiveness to assess performance of their interventions.

(2) To assess anticipated impacts or performances of interventions planned or implemented by them.

(3) To identify improper performance of interventions implemented by them in comparison with performance of other systems.

(4) Help them to make decision on selecting appropriate management interventions to be implemented in their system based on water or cost effectiveness.

5-1 SOFTWARE INTERVENTION

Formulation of rigid water cut date

Formulation of rigid water cut date scarcely requires additional expenses to irrigation management organization, but only a few farmers will suffer of yield damage by draught. Nevertheless, its impact is distinct in quickened farm operations, shortened irrigation period and reduction in water consumption. This should be the first intervention to be considered by irrigation managers of water-short systems.

Short term varieties

Planting short term varieties will be directly reflected on irrigation period and water consumption as well. Shortening growth period by 1 day produces 160 cubic meter of water per hectare. When short term varieties with appropriate characters were issued, planting short term varieties is a capable measure to improve the water use.

As mentioned earlier, Muda farmers' preference is MR 84 which growth period is 132 days. MR 123 is 114 day variety with the same yield level with MR 84 but not favored by farmers because farmers' choice ascribes not only to yield but also other factors as aforementioned.

Shift of cropping methods

The cropping method most favored by Muda farmers is wet sowing because of high profitability due to high yield and low production cost although it requires water more than the other two. Dry sowing is MADA's choice in 1st season when the dam storage is not sufficient to meet presaturation requirement. Despite reduction in agricultural income, Muda farmers well comply with the decision made by MADA who dominates irrigation supply based on the decision.

In Sri Lanka, decrease in planting area is a common measure to cope with water shortage. Compared with this, choice of cropping method would be advantageous in equity among farmers and developing farmers' water saving spirits.

Performance oriented water management

The data feedback system costed MADA US$ 1 million and some to furnish sophisticated data monitoring, transmission and processing systems. But it helped MADA to established its performance oriented irrigation management. Other than the facilities, performance oriented water management requires organization of well trained staff who monitor performances and operate the structured and DFS. Prompt actions supported by the DFS will gain farmers' credibility resulting in farmers' cooperation in irrigation system management and high performance of irrigated agriculture.

Other intervention

Organization of farmers into water users association, farm working group and so on will make considerable impacts on water use performance. Topography should be an influencing exogenous factor on extent of water use performance by management interventions. The field survey conducted in the 1st and 2nd season 1994 will be available to present data and information relevant to those factors.

5-2. HARDWARE INTERVENTION

Tertiary development

The tertiary development aimed to enhance productivity and profitability of the rice production through improvement in water delivery, field water management, transportation, mobility of agricultural machinery, labor input, etc. The tertiary development will require increase in water management loss incurred by elaborate field water depth control in direct sowing system, for instance. Water saving was not real objective of the tertiary development project.

Field survey is still on going to evaluate actual benefit and internal rate of return of the project and change in water use by the tertiary development. Data of O&M cost of the reservoirs, main canal system and internal reticular system are also being processed. Capital cost and O&M cost of hardware development obtained up to date can be summarized as in Table 8.

TABLE 8. COST OF HARDWARE DEVELOPMENT AND O&M (Unit: Rm/ha)

Hardware	Capital cost	Annual cost	O&M cost (/year)	Total cost (/year)
Reservoirs	1,460	88		
Main canal system	1,279	77		
Internal reticular system	1,395	84		
Tertiary system	9,373	562	113	675
Total	13,507	811		

Note: Capital cost (1): Total cost (Rm./ha)
Capital cost (2): Annual cost (Rm./ha/year); (1) x 6 %
Price: converted to 1993 price
O&M cost of tertiary system was referred from Project Completion Report / Muda II irrigation Project (MADA, 1988)

The unit cost of Muda I project amounted to Rm.4,134/ha including the reservoirs, the main canal system and the internal reticular system (major and secondary canal and drain systems). As development of irrigation water resources was the main aim of the Muda I Project, its water use performance was higher than the Muda II Project which aimed enhancement of productivity and profitability.

Whereas, Muda II project cost Rm.9,373/ha which was more than two times of Muda I project. Since water use performance will be little in the tertiary development, higher importance should be placed on improvement of agricultural and economic performances through improved field water management and in-field transportation. The recent water profitability in the Muda area is as shown in Table 9. Compared with the water profitability, Rm.153/1000cum of the water cost (refer Section 3-3 of this paper) based on capital and O&M costs seems to be too much. The tertiary development, therefore, will benefit the Muda farmers through increase in total profits; i.e. decrease in harvesting loss and enhancement of cropping intensity, and reduction of production cost by improved transportation and heightened machinery mobility, etc.

The tertiary development aimed to increase the annual yield by 2.8 ton/ha from 8.2 to 11.0 ton /ha (MADA, 1977). As aforesaid in the Section 3-3, the tertiary development costs Rm.574/ha/year of annual cost under transplanting method. Then, it can be calculated that yield increase by 1.3 ton/ha/year could set off this annual cost when net profit of rice is Rm.452/ton (refer Table 9). That is to say, 9.5 ton/ha is the turning point to set off the annual cost incurred by the tertiary development. This yield level will not be so difficult to attain since about 15 % of farmers have reached this level; e.g. the average yield and standard deviation of wet sowing were 4.6 t/ha and 0.8t/ha in the 2nd season 1991 and those of dry sowing were 3.1 and 0.8 in the 1st season 1992.

TABLE 9. WATER PROFITABILITY IN THE MUDA AREA (1988 - 1992)

Item	1st season	2nd season	Remarks
Total production	301,164 t	417,542 t	
Gross income	Rm.213.8 mil.	Rm.296.4 mil.	1988 -1990
Unit production cost	Rm.276.0/t/ha	Rm.244.4/t/ha	in the whole area
Net profit	Rm.83.1 mil.	Rm.102.1 mil.	
Irrigation supply	369 MCM	352 MCM	
WP 1	Rm.354/1000cum	Rm.552/1000cum	
Dam release	478 MCM	Rm.363 MCM	
WP 2	Rm.273/1000cum	Rm.535/1000cum	

Note: WP 1: WP per irrigation supply at secondary CHOs
WP 2: WP per dam release
Net profit: (Rm.130.7m+194.3m)/(301164+417542)=Rm.452/t

Construction of reservoirs

The result of Muda and Pedu Dams together with its subordinate irrigation systems furnished under the Muda I Project presents cost of dam release at Rm.24/1000cum based on the capital cost only without O&M cost which is under the progress of data processing.

Construction of reservoirs can convert the uncontrolled flow to controlled flow. Lack of suitable dam site because of flat topography in the existing watershed, however, will result in higher development cost than the existing Muda and Pedu Dams. MADA once planned to use low lying area in the command area as reservoir, but this idea had not been realized because of insufficient storage capacity.

Construction of recycling pump station

Water created by recycling systems is most economic among the hardware interventions. It is a fear that the tertiary development may increase water consumption due to elaborate field water depth control which is integral to enhance the agricultural productivity and profitability of the project. In this context, recycling use of drainage water will be an indispensable measure to promote the tertiary development, after increased water consumption should be a source of the drainage water.

6. WATER USE STRUCTURE

Assessment indicators organize some systematic linkage among them. In this linkage, a change in an indicator may influence the other indicators. Irrigation managers who plan some management intervention have to predict such consequent changes. In the Fig. 3 is an example of a linkage of the assessment indicators in the Muda area in comparison of the indicators' linkage during 1988 to 1992 with 1980 to 1984. 18 indicators/indices are identified in the chart to organize a water use linkage. Utility of the chart can be itemized as follows.

(1) To understand interrelation among indicators
(2) To predict impacts of a management intervention on water use performance
(3) To identify key indicators to assess impacts of intended interventions
(4) To minimize number of indicators to be monitored according to objectives of intended interventions
(5) To develop decision support system for scheduling of cropping

From the chart, irrigation managers can get important findings which they may not be able to recognize by single indicator. The water use situation in the Muda area can be analyzed as follows using the chart, for instance.

Dam storage

Few changes were recognized on the dam inflow but the recent decreasing dam storage or increasing dam release implies a little sustainability of irrigation resources. It will further aggravate the water shortage problem in the Muda area. Actually, insufficient dam storage precluded Muda farmers to practice wet sowing method in the 1st seasons of 1991 to 1993. Instead, farmers had to adopt dry sowing although farmers' preference is wet sowing which is more stable and profitable in production than dry sowing.

Water requirement and supply

It was designed that the water requirement of 2226 mm could be met with 967 mm of irrigation supply and 1299 mm of rainfall (DID, 1964). On the other hand, the annual total water requirement during 1988 to 1992 was 2030 mm which was supplemented by 720 mm (IRin - IRloss) of irrigation supply, 1170 mm of rainfall and 140 mm of recycling water.

The water requirement was reduced by adoption of dry sowing in the 1st season through shortening of irrigation period. Despite establishment of Data Feedback System, the shift of cropping method from transplanting to direct sowing reduced effective rainfall provably due to wasted rainfall incurred by rigid control of field water depth during early growth period of about 1 month in direct sowing culture.

Construction of recycling pump stations was MADA's another management intervention to cope with the water shortage problem. Drainage water will be still available for further recycling as only 13 % of the drainage water is presently utilized for recycling. Nowadays, about 70 % of the area is cropped by dry sowing method in the 1st season because of short of water. In order to adopt wet sowing in the whole area, additional water supply will be 370 mm (530 mm(refer Table 3) x 70 %) which is only one third of the drainage water for recycling.

Uncontrolled river flow

Ratio of used river flow over total river flow was only 14 % although river flow is given priority over dam release in MADA's irrigation management system. low utilization of river flow was attributed to discord of timing between water demand and river flow which is scanty during dry spells when water demand is high. Construction of reservoirs will be a measure to make use of 670 mm of the wasted outflow.

Rainfall

Ratio of effective rainfall decrease from 80 % during 1980 to 1984 to 60 % during 1988 to 1992. There was drastic change in cropping methods from transplanting to direct sowing between the two periods. MADA's Data Feedback System (DFS) installed in 1986 may have well functioned to enhance effective rainfall but influence of the change in cropping method may have been more than DFS.

Water consumption and drainage water

Of 2030 mm of total water supply, 1190 mm or 60 % was consumed as evapo-transpiration (ET). ET can be reduced by shortening of irrigation period by planting short term varieties.

The rest 840 mm or 40 % was drainage water which could be resources for recycling use together with 230 mm of irrigation loss. Of total 1070 mm of the drainage water, 140 mm or 13 % was recycled presently. In consideration of low percentage of recycling, further development could be expected.

Ineffective rainfall, however, will hardly be recycled as its timing is not coincide with timing of the water demands. Together with remainder of drainage water after recycling use and uncontrolled flow after diversion to irrigation intake, outflow to the sea amounts to 2440 mm annually.

6. CONCLUSION

Assessing and improving water use performance in irrigated agriculture need to assess performance of management interventions using the following three types of assessment indicators.

(1) Performance indicator on water use performance which indicates extent of target achievement of a management intervention implemented to improve water use performance
(2) Determinant indicator which indicates implementation level of a management intervention
(3) Impact indicator which indicates extent of intermediate performance of a management intervention

The three types of assessment indicators organize a linkage which illustrates water use structure and conduces to assessing and improving water use performance clarifying time series changes in water use and identify future possibility in developing local water resources.

The above hypothesis was tested in a case study of the Muda Irrigation Project, Malaysia to verify its utility.

Management interventions relevant to water use performance in the Muda area are identified as follows.

Software interventions

- Establishment of data feedback system
- Formulation of rigid water cut date
- Control of cropping methods
- Planting short term variety

Hardware intervention

- Construction of recycling pump stations
- Construction of reservoirs
- Tertiary development

Impact of interventions on water use performance can be assessed by amount of water and cost of water saved by interventions.

Cost efficiency of software intervention is generally higher than that of hardware interventions.

Shift of cropping method from transplanting to direct sowing (wet sowing) is profitable although it requires more water.

Dry sowing largely reduces water demands but reduction of profit is considerable due to low yield.

Impact of data feedback system is effective to make irrigation management performance oriented and is drastic to enhance effective rainfall.

Formulation of rigid water cut date is effective to press farmers observing official cropping schedule and results in low cost water saving.

Development of short term varieties which are favored by farmers will conduce to relieving water shortage problem.

Hardware interventions

Impact of tertiary development is less in water use performance but more emphasis should be put on agricultural and economic performance through water delivery performance.

Construction of recycling pump stations will be potential measure to solve water shortage problem in the future.

Construction of reservoirs will be available to make use of uncontrolled river flow which utility is less at the present.

A linkage chart of assessment indicators for water use performance is functional to identify water use issues in the project.

ABBREVIATION

AIPIA	Assessing and Improving Performance of Irrigated Agriculture
cum	cubic meter
DFS	Data Feedback System
DID	Department of Irrigation and Drainage, Malaysia
LCD	Lower Control Depth
MADA	Muda Agriculture Development Authority, Malaysia
MCM	million cubic meter
Muda I area	area before installation of tertiary system
Muda II area	area with tertiary system
MWD	Minimum Water Depth
Rm.	Malaysian ringgit (Rm.1 = US$ 2.6 in 1993)
UCD	Upper Control Depth

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ANNEX

ANNEX 1. YIELD AND PRODUCTION COST OF EACH CROPPING METHOD

Transplanting

MADA's survey mingled yield and production cost of three cropping methods before 1990. Therefore' there is only a few complete figures of each cropping method.

Since transplanting was dominant method until 1983, the data from 1978 to 1983 and from 1991 onward could present yield and production cost of the transplanting method. From 1991, MADA surveys the items for each method.

Yield and production cost of transplanting method

Year	1st season			2nd season		
	Yield	Cost 1	Cost 2	Yield	Cost 1	Cost 2
1978	-	-	-	3.595	794	1253
1979	4.387	884	1345	4.080	770	1172
1980	3.982	889	1335	4.009	913	1372
1981	3.758	932	1276	4.097	948	1298
1982	2.937	956	1238	3.721	935	1211
1983	2.689	967	1207	2.714	1004	1254
1991	-	-	-	4.489	932	996
1992	2.605	818	838	-	-	-

Note: Yield: ton/ha
Cost 1: in price of the year (Rm./ha; Rm.2.6/US$ in 1993)
Cost 2: in price of 1993 (Rm./ha)

In consideration that spread of Tungro disease carried by brown plant hopper severely damaged the yield from 1981 to 1984, mechanization of harvesting after 1985 was effective to cut down production cost, and yield of the 1st season 1992 is no longer representative because transplanting adopted in only 500 ha located in low lying area, the standard production cost could be 4.0 ton/ha in the 1st season and 4.5 ton/ha in the 2nd season, and production cost could be Rm.1000/ha.

Wet sowing and Dry sowing

It is generally said that rice plants under wet sowing are not tolerable to lodging in maturing stage of the 1st season which falls in rainy season with heavy rain and strong wind because of their shallow planting. It result in low yield in the 1st season although its yield in the 2nd season is close to that of transplanting.

Season	Wet sowing			Dry sowing		
	Yield	Cost	1993 cost	Yield	Cost	1993 cost
1st season 1991	3.466	710.17	736.15	3.165	590.68	612.29
2nd season 1991	4.639	751.40	788.88	-	-	-
1st season 1992	3.460	728.30	746.19	3.111	594.54	609.14
Average			757.07	3.138		610.72

ANNEX 2. IRRIGATION REQUIREMENT FOR RICE CROPPING IN THE MUDA AREA

Cropping method	Water demands	Remarks
Transplanting		
Nursery Bed	19 (10)	Soil soaking: 85(0) mm Topping surface: 50(50) mm Supplemental supply: 350(210) mm/day Ep: 5(5) mm/day SP: 5(1) mm/day Duration: 35 days 10 days: Preparation 25 days: Raising period Ratio to main field: 4% (85 + 50 + (5 + 5) x 35) x 4%
Land preparation	485(225)	Soil soaking: 85(0) mm Topping surface: 100(100) mm Supplemental supply: 300(125) mm/day Es: 5(4) mm/day SP: 5(1) mm/day Duration: 30(25) days 85 + 100 + (5 + 5) x 30
Growth period	813(616)	Ep: 4.5 (5) ET/Ep=1.25 SP: 3(1) Duration: 95 (85) days (4.5 x 1.25 + 3) x 95
Total	1317(851)	
Wet sowing		
Land preparation	585(325)	Soil soaking: 85(0) mm Topping surface: 100(100) mm Drainage loss: 100 (100) mm Supplemental supply: 300(125) mm = (5 + 5) x 30 Ep: 5(4) mm/day SP: 5(1) mm/day Duration: 30(25) days 85 + 100 + 100 + 300
Growth period	906(689)	Ep: 4.5(5) mm/day, ET/Ep=1.25 SP: 3(1) mm/day Duration: 105(95) days (4.5 + 3) x 105
Total	1491(1014)	
Dry sowing	961	Soil soaking: 85 Topping surface: 100 Supplemental supply: 776 Ep: 4.5 ET/Ep=1.25 Sp: 3 Duration: 90 days 85 + 100 + (4.5 + 3) x 90

Note: In the parenthesis are values of the 2nd season.
Dry sowing is available only in the 1st season because of the wet weather conditions for the 2nd season.

ANNEX 3. COST OF TERTIARY DEVELOPMENT FOR 25,384 HA

Year	Actual cost (million Rm)		Cost in 1993 price (million Rm)
	Civil work	Base cost	
1979	12.57	17.77	27.04
1980	6.58	11.75	17.65
1981	6.79	15.14	20.73
1982	12.01	19.29	24.98
1983	12.20	18.62	23.25
1984	12.71	20.40	24.59
1985	14.48	18.06	21.51
1986	12.67	17.51	20.91
1987	6.70	12.17	14.42
1988	8.14	11.07	12.79
1989	8.10	12.80	14.38
1990	8.26	14.23	15.68
Total			237.93

Note: Unit cost of tertiary development: Rm.9,373/ha in 1993 price
Base cost includes land acquisition and engineering and supervision.
Data source: Project Completion Report, MADA.

ANNEX 3. COST OF DATA FEEDBACK SYSTEM

Capital cost (in 1993 price)

Telemetry system		
	Hydrological instrumentation	Rm.763,521
	Telemetry system	Rm.1,699,536
	Civil works	Rm.393,335
VHF tele-communication system		
	3 Channels	Rm.358,595
	Tower	Rm.17,407
	Base building	Rm.11,911
Computer system		Unknown
Total		Rm.3,244,305

Annual cost based on 15 year durability and 10 % salvage value Rm.194,658

O&M cost (in 1993 price excluding cost for the computer)

Maintenance cost	Rm.190,000
Direct staff cost	Rm.211,200
Leasing and licensing of radio channel	Rm.10,000
Stationary	Rm.17,200
Other maintenance cost	Rm.35,000
Total	Rm.463,400

Total annual cost Rm.658,058

ANNEX 4. RICE PRODUCTION COST (AVERAGE OF 1986 - 1990)

(Unit: Rm/ton)

Season	Cost	Cost in 1993 price
1st season		
1986	250.77	299.41
1987	249.25	295.25
1988	237.66	274.59
1989	243.20	273.21
1990	215.72	237.72
Average		276.04
2nd season		
1986	234.40	279.86
1987	206.18	244.23
1988	221.73	256.18
1989	208.01	233.68
1990	188.83	208.09
Average		244.41
Overall average		260.41

ANNEX 5. COST OF ESP STATION

CAPITAL COST OF ESP STATIONS

(Unit: Rm)

Station	Capacity	Civil work	Pump cost	E. wiring
A5	1.1 cum/s	101,066	161,988	17,391
PN15	1.7	124,120	191,388	9,285
PS4	3.4	145,102	437,671	44,616
S3	3.4	140,469	352,817	32,243
Alor G.	2.3	156,253	282,466	136,966

Note: E. wiring: Electricity contribution

CAPITAL COST OF ESP STATIONS PER CAPACITY (Rm1000/cu m/s)

Station	Capacity	Civil work	Pump cost	E. wiring
A5	1.1 cum/s	92	147	15
PN15	1.7	73	113	5
PS4	3.4	43	128	13
S3	3.4	41	104	9
Alor G.	2.3	68	123	60
Average		63	123	20

O&M COST OF ESP STATIONS

Year	O&M cost (Rm/year)	1993 price (Rm/year)	Water volume (MCM/year)	Water cost (Rm/1000m^3)
1987	283,511	335,831	51	6.6
1988	446,389	515,751	102	5.1
1989	519,363	583,458	135	4.3
1990	554,574	611,130	197	3.1
1991	313,829	325,308	54	6.0
1992	406,543	416,526	130	3.2
Total/Average		2,788,004	669	4.2

FIG. 1. SEASONAL WATER REQUIREMENT BY CROPPING METHOD

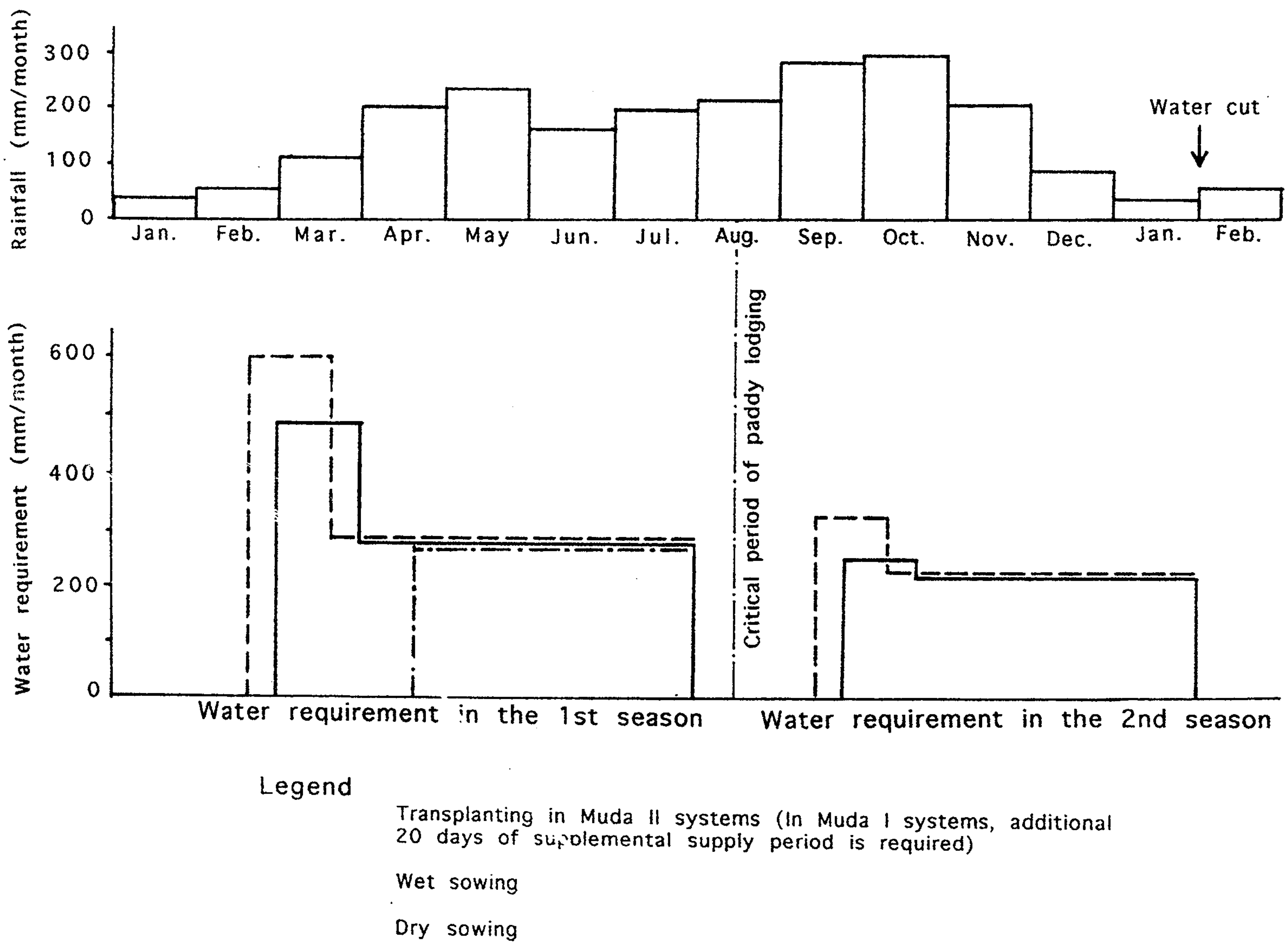
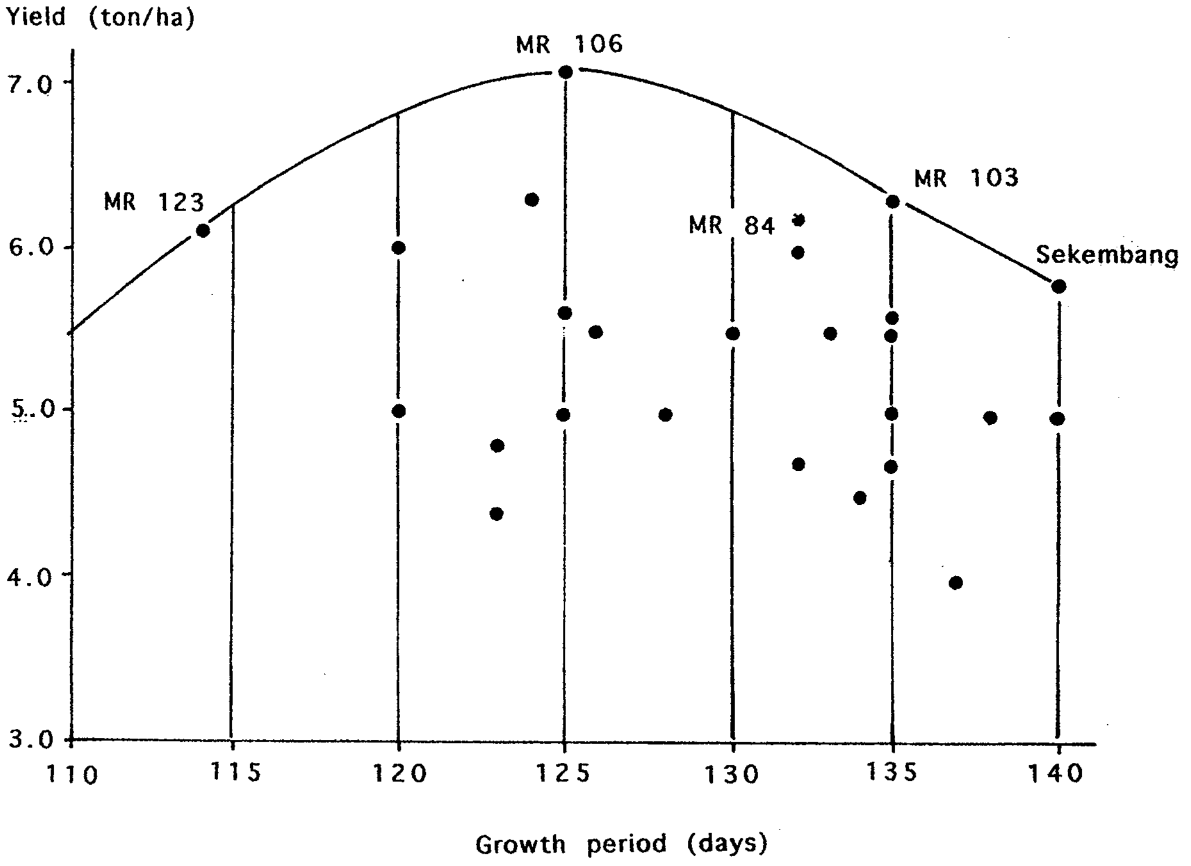
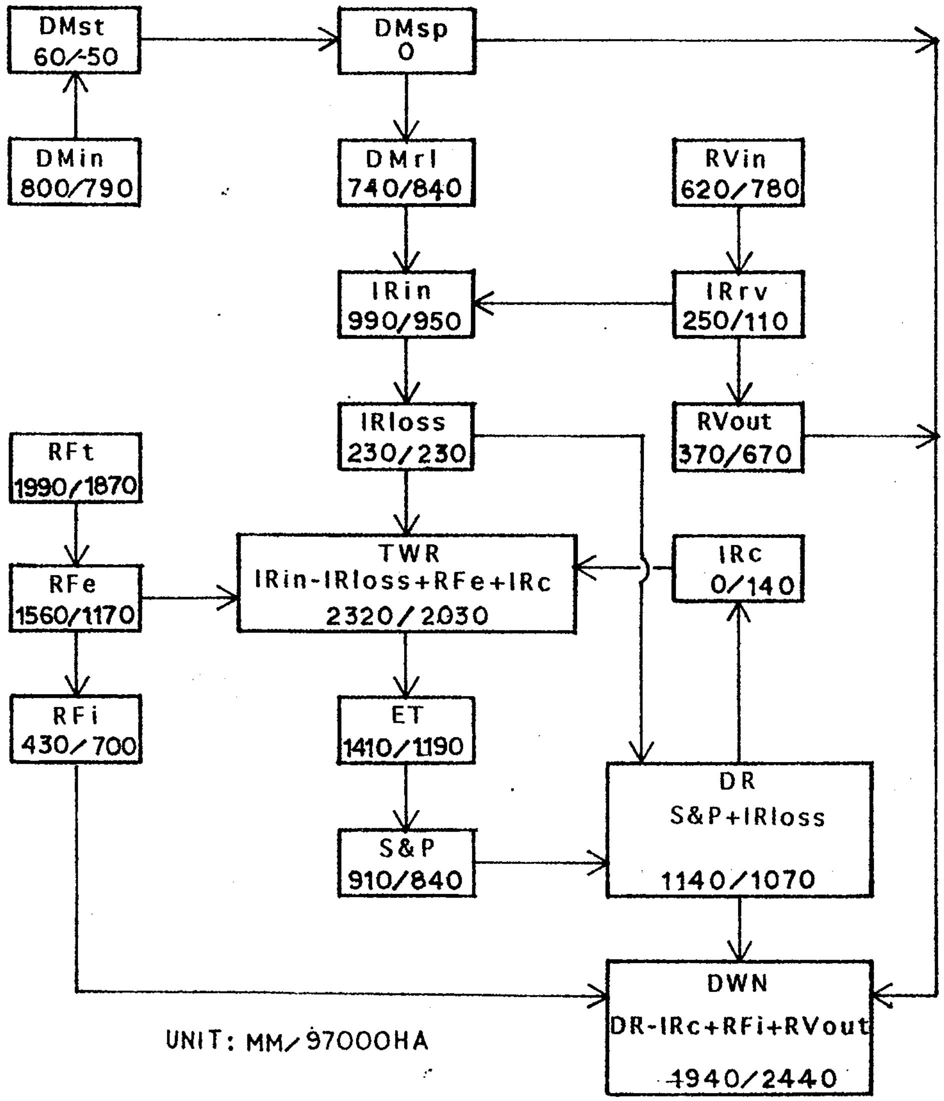


FIG.2. GROWTH PERIOD AND YIELD BY RICE VARIETIES



Data source: MARDI, Seberang Perai

FIG. 3. WATER USE STRUCTURE IN THE MUDA AREA (1980 – 84) / (1988 – 92)



Legend

DMin: Dam inflow (DMst+DMsp+DMrl)
DMst: Change in dam storage
DMsp: Dam spill
DMrl: Dam release

IRin: Intake (DMrl+IRrv)
IRin: Diverted river flow
IRc: Recycled drainage water
IRloss: Canal loss

RVin: Uncontrolled river flow
RVout: Unused river flow (RVin-IRev)

RFt: Total rainfall
RFe: Effective rainfall
RFi: Ineffective rainfall

TWR: Total water requiremen
ET: Evapo-transpiration
S&P: Seepage loss

DR: Drainage water
DWN: Outflow to the sea