Main Irrigation System Management for Rice-Based Farming Systems in Indonesia

Suprodjo Pusposutardjo
Lecturer and Head, Department of Agricultural Engineering
Faculty of Agricultural Technology, Gadja Mada University,
Yogyakarta, Indonesia

Hammond Murray-Rust
Senior Irrigation Specialist,
International Irrigation Management Institute, Colombo, Sri Lanka

Sukarso Djunaedi
Senior Staff, Directorate Irrigation I
Directorate General of Water Resources Development
Department of Public Works, Indonesia

INTRODUCTION

FOR THE LAST ten years, the Government of Indonesia has bee promoting crop diversification in irrigated rice fields. Crop diversification (horizontal diversification) is a part of an integrated effort to achieve the objectives of

a. Sustaining and improving food self-sufficiency.

b. Increasing agricultural production to provide raw materials for industry and export.

c. Increasing farm productivity and value added of agricultural products.

d. Increasing farmers' income and improving their welfare.

The crop diversification program in irrigated rice fields also facilitates the operation and maintenance of irrigation structures according to the defined rules, especially in the main system. This is attained by:

a. Allowing the canals to dry up for maintenance work.

b. Decreasing the burden of operation and management during the dry season when normally there is a shortage of water.

c. Increasing the flexibility to allocate water for other uses which are steadily increasing and for supplemental irrigation of two rice crops and one upland crop (palawija) only. Therefore, the crop diversification program will restore the utilization of the irrigation network of Indonesia to its functional design.

Irrigation Management in the Main System

The main system in Indonesia is commonly associated with technical irrigation. These are the irrigation systems which have permanent structures and the distribution of water is fully controlled and measured.

The technical irrigation systems in Indonesia by 1988, covered an area of 2,534,613 ha, representing 57.8 percent of the total irrigated areas. About 1,934,387 ha (76.3 percent) are located in Java. The general description of the irrigation system and the respective cropping intensity for rice are presented in Table 1.

Table 1. Irrigated area and rice cropping intensity, 1988.

Irrigation status	Areas (ha)		One rice crop percent	Two rice crops percent
	lava	Indonesia		
Technical irrigation	1,934,387	2,534,613	17.6	82.4
Semi-technical irrigation	415,244	1,180,716	29.1	70.3
Simple/village irrigation	376,621	612,432	43.0	57.0
Total	2,726,252	4,387,781		

2. The scope covers operation and maintenance of the irrigation networks together with their accessory structures from the intake to the tertiary canal, 50 meters downstream of the tertiary offtake.

3. The main system shall be responsible for distributing water from the intake structure down to the tertiary offtake according to the scheduled plan.

4. The operation and maintenance of the main system shall be the function and the responsibility of the Local Government.

5. Associated with irrigation water management as a whole, the Local Government (Local Irrigation Committee) makes a plan for the provision and allocation of irrigation water for different uses. This plan is decided by the Head of the Local Government on behalf of the Head of Local Irrigation Committee, at the latest, one month before the rainy season cropping begins.

The operation and maintenance of the imgation networks are also supervised by the Local Government. It establishes protection zones along and around canal bodies and irrigation structures, prohibits excavation in the protected zone to avoid water losses, and prohibits installation, modification or demolition of any structure which may disturb the main function of the irrigation network. The division of responsibility is shown in Figure 1.

SYSTEM MANAGEMENT FOR RICE-BASED FARMING

Management requires that there should be a set of objectives for which all subsequent activities must be oriented. Irrespective of the individual objectives of a particular irrigation system, the three major objectives of production, equity and sustainability should be considered. It is important that the three objectives must be achieved simultaneously.

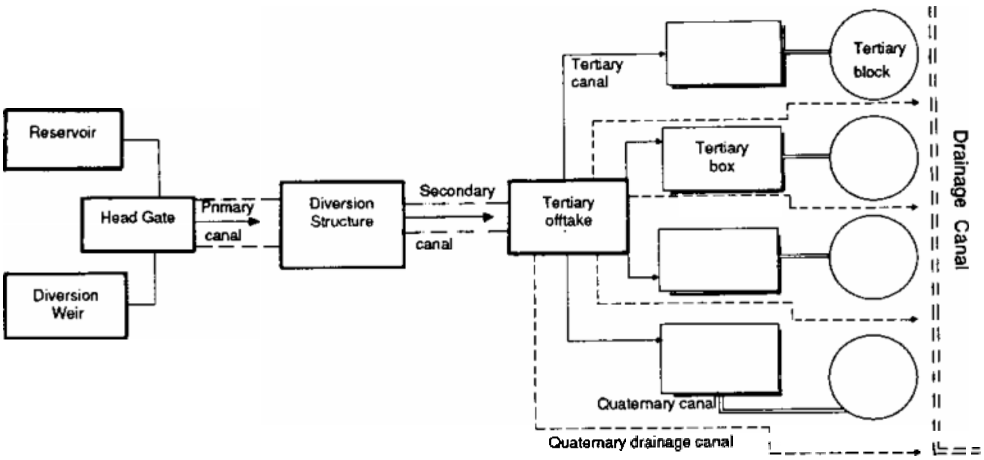
Equity in Water Distribution

Two sample case studies in the coastal plain of irrigated rice fields showed that inequity in water distribution resulted in a water shortage during the dry season and an excess water during the wet season in some parts of the command areas.

In the West Situbondo Irrigation Scheme, it has been observed that there is inequity of water distribution between the head and tail sections of the system. In terms of water sufficiency received by the farmers along the three sections of the secondary canal, head, middle and tail sections, it was shown that the head and middle sections received more water during the dry season than the tail section

(Table **2).** However, this did not have much influence on the cropping pattern and the yield of rice (Table **3).** Relative difficulties to obtain sufficient water in the middle and tail sections can be noticed from the area with cropping patterns R-U-U (one rice crop and two upland crops) and the lowest yield of the third crop in the tail section.

Figure 1. ***Delineation of responsibility** on **some activities of (technical) irrigation management.***



Systematic name

Water resource — Main irrigation network |← 0 — Tertiary irrigation and drainage network |←

Managementaulhorily and regulation of irrigation water and irrigation network responsibility

Local Government (Irrigation Committee) ← — Water Users' Fanners Association (P3A), Subak. or owner → Government

Planning of inigalion water supply responsibility

Local Irrigation Committee proposes lo Local Government.
Local Government adjudicates the plan. IC implements the plan → P3A, Village, Subak, other uses, submit applicalwn to IC

Operation and maintenance of irrigation network responsibility

|← Local Government →| ← P3A, Village, Subak, owners → |← L G

Table 2. Water distribution performance of the secondary canal, West Situbondo Irrigation Scheme (WSIS).

Sufficiency Level	First rice crop			Second rice crop		
	Head (N=270)	Middle N=266)	Tail (N=270)	Head (N=270)	Middle N=266)	Tail (N=270)
Water sufficient at all times	62.5	97.6	78.9	52.1	53.5	36.3
Water sufficient in 4 to 6 months	4.2	2.4	5.3	13.2	27.9	47.1
Water sufficient in 2 to 4 months	33.3	0.0	10.5	34.7	18.6	17.6
Water sufficient in less than 2 months	0.0	0.0	5.3	0.0	0.0	0.0

Table 3. Distubution of cropping pattern and rice yield along the secondary cannal of West Situbondu Irrigation Scheme.

Location with respect to intake		Percent of sample				Yield of rice (t/ha)		
		R-R-R	R-R-U	R-U-U	R-R-F	I	II	III
Head	(n=270)	58.3	41.7	0.0	0.0	4.58	3.97	2.77
Middle	(n=266)	61.7	34.0	2.1	2.2	5.92	3.47	2.83
Tail	(n=270)	62.2	35.2	1.1	0.0	4.78	4.85	2.17

Using wetness index criteria (average soil moisture content in the command area), the study in the Cikeusik Irrigation Scheme indicated that the tail section of the command area also had drainage problems during the rainy season beside a water shortage during the dry season (Table **4).** Rapid changes of water status in PB VII and VIII from wet to dry and wet again in accordance with the beginning of the rainy season give evidence to the inequity of water distribution along the main system. Further study indicated that based on soil moisture status, only 42 percent out of the 136-ha area could be grown to upland crops (Pusposutardjo and Arif **1990).** The potential area for upland crops in the tail-end portion of the system has decreased because of salt water intrusion during the dry season (Pusposutardjo and Arif **1990).**

Equity could also be influenced by the size of the irrigation system. **For** systems with smaller command areas (100-300 ha), inequity in water distribution along the main system is not significant. As a result, the influence of inequity in water distribution to the difference of cropping pattern in the whole command areas is also not pronounced (Anonymous 1988). Small irrigation schemes are usually located in the hilly areas and drainage may not be a problem. In this case, the willingness of farmers to grow upland crops depends much on the availability of water during the dry season and on economic considerations.

Accuracy in Annual Planning

The plan of the irrigation season is made by the Local Irrigation Committee (LIC) and approved by the Head of the Local Government. The plan for the season is then implemented by the LIC. Based on the plan, the LIC allocates water for different uses and distributes it according to the procedure of operation and maintenance. The irrigation plan also contains the schedule for routine maintenance by drying the canal (shutting the flow).

Vermillion et al. showed that enough information on previous experience is not used in the process of preparing the annual crop plan, and that the plan is not readily transformed into a set of operating rules. Thus, while the plan may call for a very limited area of rice in the first dry season, the system is actually operated in such a way as to encourage farmers to plant extra rice.

Since the irrigation season plan has to be made, at the latest, one month before the start of the planting season, the accuracy of planning with respect to the occurrence of rains or the availability of water in the main water course is very important. When the farmers deviate from the schedule, problems related to water supply and demand occur.

The use of 80 percent dependable rainfall in planning cannot reliably match the real condition. Studies conducted in three large irrigation schemes of Citagampor Project and in three small irrigation schemes in East Java indicated that farmers still rely more on their experience in predicting water based on the prevailing rainfall rather than on the planned irrigation schedule (Anonymous **1987;** Anonymous 1988). Normally, farmers start land preparation whenever the cumulative rainfall accounted from the latest minimum rainfall reaches 300-400 mm. The difference between the irrigation plan and the existing activity in land preparation ranges from 10 to 14 days.

Table 4. Distribution of soil moisture status and the existing crop along Pabedilan Secondary Canal of Cikeusik Scheme during the dry season, 1989.

Location of tertiary block	Month				
	July	August	September	October	November
lead (MTR V)					
a. Soil moisture status	(0,10,0)	(5,10,15)	(5,5,20)	(10,5,15)	(0,20,10)
b. Existing crop		Rice (D)	Rice		
		Corn	Corn (D)	Corn (D)	Corn
		Tobacco	Tobacco	Tobacco	
		Sugarcane	Sugarcane	Sugarcane	
ugarcane(D)					
		Mungbean	Mungbean	Mungbean	
		Onion	Onion	Onion	
liddle (SR 111)					
a. Soil moisture status	(10,0,0)	(10,15,5)	(0,5,25)	(0,15.15)	(10,5,15)
b. Existing crop		Rice (D)	Rice		
		Corn	Corn (D)	Corn (D)	
		Onion	Onion		
		Sugarcane	Sugarcane	Sugarcane	
ugarcane(D)					
			Chili	Chili	Chili
ſiddle (PB III)	(0,0,10)	(0,0,30)	(0,0,30)	(10,5,15)	(5,20,5)
a. Soil moisture status	·	Onion(D)	Onion(D)	Onion(D)	Onion(D)
b. Existing crop		Sugarcane	Sugarcane	Sugarcane	Sugarcane
		Mungbean	Mungbean		
			Chili	Chili	Chili
'ail (PB VII & VIII)					
a. Soil moisture status	(5,5,0)	(10,20,0)	(0,0,30)	(10,0,20)	(25,5,0)
b. Existing crop	Rice(D)	Rice(D)			
		Onion(D)			Onion(D)
	Chili				
			Green manure	Green manure	Green manure

Source; Sukirno (1989).

Notes: (0,10,0) -number of days corresponding to wetness index (wet, moist and dry, respectively).
Wetness index: the average soil moisture in the area:
wet - saturated or stagnant.
moist - suitable for upland crop.
dry - insufficient for any crop.
D - dominant crop.

Since cropping is continuous, a delay of 10-14 days will shift the peak water demand to the land preparation period for the next (second) rice crop. When this occurs, maintenance of irrigation structures becomes a problem because the flow cannot be shut off since some farmers will still need water. Normally, the second season rice crop begins in the middle of the rainy season and farmers will not grow upland crops because the rice field is still too wet. Moreover, they expect to receive sufficient water from rainfall for growing a third rice crop.

In the implementation of the irrigation plan, several modifications or changes are commonly made. These are just based on experience and the accuracy of the plan is questionable. Farmers, therefore, do not rely on the irrigation schedule and oftentimes grow an unauthorized rice crop during the dry season. The ratio of unauthorized to authorized dry season rice crop is in the range of 50 to 100 percent.

Rotational Irrigation

When rotational irrigation is adopted, travel time of water is particularly important. Depending on the discharge being delivered, it may take a considerable time to fill the canal with sufficient water to generate a manageable stream size into each tertiary block scheduled for irrigation. If the stream size is too small to enable farmers to effectively distribute water within a tertiary block, the water has limited utility. Rotational schedules should thus be based not on the time of delivery at the head of the main or the secondary, but on the duration of useful discharges that can be guaranteed to be delivered to the head of each tertiary block.

Mawardi 1990 has demonstrated that in most of the canals studied, travel time is relatively easy to predict. The largest variation appears to result from the initial discharge at the head of the system, but even with this uncertainty, it appears feasible to design rotational irrigation schedules that make better allowance for travel time at the start of each rotation.

Rotational schedules have to be effectively implemented to meet equity objectives. If the schedule becomes erratic, farmers will lose confidence that their next turn will come when expected, and will probably either interfere with gate settings, thereby disrupting control over water distribution, or may as a last resort end up destroying structures.

IIMI's research has shown that rotational schedules are not rigidly adhered to (Murray Rust 1990). In 1988, part of the reason for this appeared to have been because the schedule was not very equitable. In 1989, the implementation was somehow improved, with most deviations being related to periods when supplies were greater than expected, and more farmers could obtain water than was initially planned.

TECHNICAL CONSTRAINTS IN MAIN IRRIGATION SYSTEM MANAGMENT

The last inventory conducted in 1988 by the Directorate Irrigation I of the Directorate General of the Water Resources Development (DGWRD) showed that the quantity and diversity of the structures in Indonesian irrigation systems were enormous (Table 5). All these structures have to be managed under limited

Table 5. Physical infrastructure of the irrigation network in *Indonesia.*

Item	Quantity
Number of irrigation schemes	6,731
Total command areas (ha)	4,819,470
Water resources: rivers. reservoirs, springs and others	14,859
Intake structures: pump. moving weir, fixed weir, free intake. etc	21,874
Structures in the delivery canal: sand trap, flushing gate, diversion structure, siphon, chute, drop structure, etc.	157,196
Structures in the drainage canal: bridges, culverts, spillway, etc.	10,968
Structures in the side canal: bridges, culverts, spillway, etc	688
Secondary canal (km)	62,823,680
Drainage canal (km)	19.582,112
Supply canal (km)	988.913,
Side canal (km)	623,286
Road inspection (km)	10,353,948
Cover dikes (km)	2,540,994

facilities, manpower and funds. Obviously, the operation and maintenance of the main irrigation system have already become a heavy burden on the government.

The limited facilities, manpower and funds also create related technical problems in the main system. These are:

1. ***Insufficient* hydrological data.** Hydrological data in terms of quantity, quality and time series are insufficient to back up the operation of the main system properly. Most irrigation schemes (especially out of Java) were designed and constructed using very limited hydrological data. These data have been collected for a few years (1-5 years), only during the implementation

of the imgation projects. Because of the very limited data, the operation of the irrigtion scheme is usually based on trial and error. Consequently, this affects the management of the system.

2. *Poor physical condition of the structures.* Results from several studies (Anonymous 1984; Anonymous **1987;** Anonymous 1988; Susanto 1986) showed that most of the water measuring devices (especially the Romijn type) were not in good condition. The error of measurement may deviate from 30 to 105 percent of the standard reading. Very high variation between the actual and the estimated flow causes some parts of the areas to receive more water than the others as shown in Table **2.** The error also results from improper construction (mostly with the Flume type), incorrect location, and poor maintenance. Poor canal maintenance causes considerable conveyance losses. **These losses vary according to the length and condition of the canal,** and discharge. A study on canal losses showed negative values possibly because the canal is located below the rice field areas. Conveyance losses of 5-10 percent are reasonable values for canals less that 2 km long. These increase to as much as 16-20 percent if the total length of the canal reaches 4-5 km.

3. *Insufficient drainage facilities.* Although in the design of irrigation systems the drainage requirement has been considered, drainage facilities deteriorate very fast. Farmers usually do not know the benefits of having good drainage facilities. They consider drainage facilities to be useless canals. The destruction of drainage canals at the tertiary level occurs mostly in the sugarcane areas. Considering that some upland crops are very sensitive to excess water, more attention has to be given to improving drainage facilities. Otherwise, the program on crop diversification in irrigated rice fields will not be very successful.

4. *Water resource.* More than *80* percent of the irrigation schemes in Indonesia are run-of-the-river type. These systems are very sensitive to the hydrological condition of the catchment area to store water from rainfall. As the condition of the catchment areas changes very rapidly due to deforestation, the river discharge also fluctuates very rapidly between peak flow and base flow. Evidently, it creates a problem in the management of the main system.

5. *Inadequate manpower and facilities.* The number of irrigation personnel with permanent status as government officials is still below the standard requirement (Djunaedi 1990). Most of those who are involved in operation and maintenance of the main system are monthly wage earners who are not motivated to achieve high quality of work. Besides inadequate manpower, in operation and maintenance of the main system there is also the problem of lack of transportation facilities to carry out field operations. A gatetender, for instance with a service area of 750 to 1,000 ha, is only provided with a

bicycle. With this transport, he has to monitor and record the daily flow and crop area, attend weekly meetings with water masters, supervise maintenance work, give guidance to water users' associations, and act as the irrigation extension officer. Similarly, the water masters who have service areas of more or less 5,000 ha are only provided with motorcycles for their transportation.

6. *Lack of a standard manual for operation and maintenance.* The gravity imgation system is influenced by topography. In the hilly areas, more structures are required to control the flow. In the flat areas, more check structures are required to obtain the needed head. These characteristics of the gravity irrigation system should be considered in the Manual for Operation and Maintenance. At present, however, this kind of manual is not yet available. A manual specifying the conditions of the area will facilitate the management of the system.

RECOMMENDATIONS FOR CHANGES IN IRRIGATION MANAGEMENT FOR RICE-BASED FARMING

Considering the objective of maximizing irrigation benefits in the dry season in the rice-based cropping system, Murray-Rust (1990) made an overall assessment of the results obtained from the component studies and indicated three main sets of tasks — rotational irrigation, continuous irrigation and planning for long-term objectives — where quick and effective progress can be made.

Rotational Irrigation

Rotational irrigation is a mechanism by which scarce water can be allocated to as many farmers as possible. It, therefore, requires greater top-down control over water than when water is relatively abundant. Given that rotations are almost inevitable in the dry season in the main and secondary canal systems, the following recommendations are presented

1. Rotational irrigation should be introduced when required for hydraulic reasons, and not based on values of factor-K because it is possible to have high factor-K values at low discharges.

2. The area planned for irrigation for each day has to take into account the ability of the irrigation agency staff to maintain proper control at the structures used to delimit rotational boundaries, and to minimize the number of gate operations required.

3. The size of rotational units should aim at maximizing equity by taking into account travel time, conveyance losses and other hydraulic conditions.

4. Within-season scheduling of rotational irrigation should be based on a priority system that guarantees water to a certain area, but specifying which areas would get additional irrigation water if supplies are greater than expected.

5. Once publicized, rotational schedules must be strictly adhered to so that farmers can have confidence in obtaining water according to the priorities already established. Failure to deliver water on schedule should be viewed as a serious mistake of the management.

6. The rotational schedule has to be agreed upon between farmers and irrigation staff well in advance of implementation and should, over time, following seasonal assessment of the benefits obtained, be modified to become an established and routine component of irrigation practices.

Continuous Imgation

From the perspective of improving dry-season irrigation performance, the focus of irrigation managers must be to manage excess water by reducing discharges at every opportunity, while still meeting the crop water requirements. Through good management, it is possible to move to a situation where farmers do not object to reduced deliveries because they are confident that the system will deliver water when needed. It should, therefore, consider the following:

1. During the wet season, delivering more water than required should be viewed as a management failure because it may have subsequent negative implications on the establishment of nonrice crops. This includes reducing discharges during periods of high rainfall or when crops are nearing harvest and have lower water requirements.

2. When supplies are greater than demand, more attention should be given to monitoring drainage conditions or water tables than to discharges entering tertiary blocks. In this way, it is possible to move towards a needs-based allocation of water under favorable water supply rather than relying on theoretical calculations of demand.

Planning for Long-Term Objectives

Most irrigation management strategies tend to concentrate on the short-term problems of matching available supplies to demand at field level. While this achieves short-term production objectives it frequently leads to an inherently inequitable pattern of irrigation. Access to water is determined not by equity or the need to share benefits of irrigation water to as many people as possible, but by the ability of farmers to plant crops quickly. Once crops are planted, then demand-based water allocation principles no longer meet equity objectives.

This situation creates a genuine dilemma for those involved in the planning process because they have to decide whether equity is an important objective. For the irrigation manager, this is particularly difficult because achieving greater equity while maintaining production requires much greater managerial inputs than only meeting production goals. However, the combination of increasing pressure on land and water resources makes it imperative that equity is given as much importance as production, if the benefits of imgation investments are to be maintained. The following recommendations aim at ways of achieving these dual objectives.

1. The annual planning process should move towards allocation of water based on the area capable of being imgated to minimize discrepancies in cropping intensities between head-end and tail-end areas. This would result in allocation of water on a proportional basis using area as the primary determinant rather than the existing cropping pattern.

2. Where there are significant differences in soils or drainage conditions, the allocation should be modified to take into account the differences in water requirements. In such cases, there may also be merit in considering zoning, such as permitting poorly drained areas to obtain water for two rice crops instead of one because there is little opportunity for nonrice crop production.

3. In cases where water supplies in the peak of the dry season are very limiting, the annual plan should include a between season allocation, so that there is an overall level of equity developed over a period of two or three years.

4. There must be a clear linkage between the annual plan and the operational plan of the irrigation manager. An annual evaluation process should be done to determine whether deviations from the plan were the consequences of weaknesses in implementation or in planning.

5. It is particularly important that plans be properly followed in the transition period from the wet to the dry season to avoid too much area for more water-demanding crops which cannot be properly irrigated when water supplies begin to decline.

Complementing the above-cited strategies, several options have also been identified to address the problems in the operation and maintenance of the main system as a part of an integrated management activity. These are as follows:

1. Providing facilities and personnel to meet the minimum standard level.

2. Giving special attention to improve data-gathering and the processing technique to provide more reliable information.

3. Improving the information management system to minimize information losses and to maximize the use of information and data already gathered.

4. Providing different standard procedures of operation and maintenance according to the characteristics of the irrigation scheme, such as the elevation and topography of the command area. Developing a standard procedure of operation and maintenance (in the form of a manual) can be a long-term program.

5. Providing sufficient and reliable hydrological data, including the calibration of water-measuring devices.

6. Providing a simple but accurate method to estimate probable rainfall and river discharge. Related to this technique is the procedure to estimate the amount and distribution of available soil moisture over irrigated areas.

References

Anonymous. 1984. Penelitian Pengelolaan Air lrigasi di Prosida Sub Proyek Pekalen Sampean Dalam Rangka Salah Satu Persiapan Completion Report Rehab VII. Final Report. Fakultas Teknologi Pertanian, University of Gadjah Mada (UGM).

Anonymous. 1988. Penelitian Pengelolaan Air Tingkat Tersier di Daerah Pengembangan Irigasi Dengan Persanserta Petani di Wilayah Kerja Progasi Madiun-Jawa Timur. Final Report. Fakultas Teknologi Pertanian, UGM, Yogyakarta.

Directorate General for Food Crops and Agriculture. 1990. Department of Agriculture Data Bogor.

Directorate of Irrigation I, Directorate General for Water Resources Development. 1988.

Djunaedi, S. 1990. Operasi dan Pemeliharaan Jaringan Irigasi Direktorat Irigasi I, Direktorat Jederal Pengairan. Jakarta.

Final Report of Water Management Study in Pekalen-Sampean Subproject, Department of Agricultural Engineering (DAE), University of Gadjah Mada (GMU). 1984. Yogyakarta, Indonesia.

Mawardi M. 1990. Alternative improvements of time allocation in rotational irrigation based on canal performance. Paper presented at the Indonesia Workshop on Irrigation Management for the Dry Season in Rice-Based Cropping Systems, Yogyakarta, Indonesia 13-14 June 1990.

Murray-Rust, Hammond. 1990. Irrigation management strategies for the dry season in rice-based cropping systems. Paper presented at the Indonesia Workshop on Irrigation Management for the Dry Season in Rice-Based Cropping Systems. Yogyakarta, Indonesia. 13-14 June, 1990.

Pusposutardjo, S. and S. S. Arif. 1990. Drainage condition affecting options for change in rice-based systems. Paper presented at the Indonesia Workshop on Irrigation Management for the Dry Season in Rice-Based Cropping Systems. DAE/GMU-IIMI, Yogyakarta. 13-14 June, 1990.

Sukirno. 1989. Soil moisture status in tertiary block of irrigated area. Research report submitted to IIMI under Contract No. 937-INI-IIMI-ADB.

Susanto. S. 1986. Pendayagunaan Air Permukaan DAS Sampean Hulu. Thesis submitted to Graduate School Program, GMU. Yogyakarta.