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DETERMINATION OF IRRIGATION PERFORMANCE INDICES FOR PADDY CULTIVATION

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DETERMINATION OF IRRIGATION PERFORMANCE INDICES FOR PADDY CULTIVATION

By

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Dedicated to

Mohammad Noh Bin Haji Abdul Mumin

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LIST OF ABBREVIATIONS

CRW	Crop Water Requirement
CRWS	Cumulative Relative Water Supply
Delta S	Storage water elevation
DID	Department of Irrigation and Drainage
Dr	Drainage
DSR	Drainage Supply Ratio
Epan	Pan evaporation
ER	Effective Rainfall
Et	Evapotranspiration
EWUI	Effective Water Use Index
IADP	Integrated Agricultural Development Project
IRR	Irrigation
JPS	Jabatan Pengairan dan Saliran
KADA	Kemubu Agricultural Development Agency
MADA	Muda Agricultural Development Agency
PCI	Plot Consumption Index
RF	Rainfall
S&P	Seepage and Percolation
*.cfg	Configuration files
*.dat	Data files
*.lst	List files
*.xl	Deliminated files
*.xls	Excel files

Abstract of this thesis presented to the Senate Of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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July 1999

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Evaluation and monitoring of paddy irrigation schemes (field plot level) traditionally use conventional indices, namely, Relative Water Supply (RWS) and Water Use Efficiency (WUE). Where continuous irrigation was practice, low WUE and high RWS were obtained giving the impression that little water management had been carried out. This is partly blamed on the incorrect use of these indices because the aim of the agency is different from those for which RWS and WUE were developed. A study at field plot level was conducted in Bagan Serai, Perak for one main season to measure the components of water balance in an irrigated paddy field. The components of the water balance were individually measured using a range of equipment. Observations were made to find indicators that can show the performance of water management according to the aim of the agency. These indicators were

incorporated in the proposed indices. Plot Consumption Index (PCI) and Effective Water Use Index (EWUI) were developed and proposed to evaluate and monitor the irrigation performance at field plot level. These indices were developed in line with the aim of the agency and that was to maintain the 'Design Water Depth' (DWD) in the field. DWD is the depth of water that should be maintain throughout the planting season. Results of the components of the water balance were used to calculate WUE, RWS, PCI and EWUI. For most of the season, daily values of EWUI were less than 1 but more than 0, indicating that excess water was supplied. Some days recorded negatives values ranging from -0.1 to -6.9.On these days there was heavy rains and the field was flooded. On the weekly basis, week two had a value of 0.32 while wek six had a value of 0.16, while the weekly basis, week tw had a value of 0.32 while week six had a value of 0.16, while tha last week recorded 2.71, indicating under supply, a situation commensurate with the end of season. All other weeks indicated excess or flood conditions by its negative values.

For the PCI index, daily values of between 0 to 1 was recorded for most days. There were however eight days when values were negative, indication surplus or flood conditions. On a weekly basis, only the first week had a negative values of -0.44. All other weeks were within the range of 0.33 to 0.97. It was found that the values of WUE and RWS were much higher than that of PCI and EWUI. However, all these indices indicate that the plot had been excessively over irrigated. This shows that the proposed indices give comparable results and hence their contribution to water management can be considered. Further detail analysis and research should be carried out, so that the effective use of these indices can be justified.

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Penilaian dan pengawasan skim pengairan (dalam petak sawah) selalunya menggunakan indek-indek Relative Water Supply (RWS) and Water Use Efficiency (WUE). Di kawasan-kawasan yang mempraktikkan pengairan berterusan, nilai WUE adalah rendah dan nilai RWS adalah tinggi. Ini menunjukkan tahap pengurusan air adalah pada tahap yang terendah. Ianya disebabkan oleh penggunaan indek-indek yang kurang sesuai. Satu kajian telah di lakukan di Bagan Serai, Perak selama satu musim penanaman untuk mengukur komponen-komponen kesimbangan air. Komponen-komponen kesimbangan air telah diukur secara berasingan dengan menggunakan pelbagai alatan. Penelitian dilakukan untuk mendapat 'penunjuk' yang boleh menunjukkan prestasi penggunaan air yang menepati matlamat agensi yang

berkenaan. Penunjuk-penunjuk ini digunakan di dalam indek-indek yang dicadangkan. Plot Consumption Index (PCI) dan Effective Water Use Index (EWUI) telah dibuat dan dicadangkan untuk menilai dan mengawas prestasi pengairan. Indek-indek ini dibuat selari dengan matlamat agensi untuk menstabilkan paras air di dalam sawah. Keputusan komponen-komponen kesimbangan air telah digunakan untuk mengira WUE, RWS, PCI dan EWUI. Kebanyakkan hari didalam musim menunjukkan nilai harian Indekx EWUI lebih daripada 0 tetapi kurang daripada 1. Ini bermakna bekalan air adalah berlebihan. Didapati beberapa hari telah dicatatkan nilai negatif diantara -0.1 hingga -6.9. Terdapat beberapa hari yang menunjukkan hujan lebat dan banjir telah berlaku. Berasaskan kepada nilai mingguan, didapati nilai 0.32 bagi minggu kedua an nilai 0.16 bagi minggu keenam. Pada miggu terakhir nilai 2.71 diperolehi berkeadaan kurang bekalan dan satu bacaan yang diselaraskan dengan akhir musim tanaman. Minggu -minggu lain menunjukkan nilai negatif dimana bekalan terlalu banyak.

Bagi Indeks PCI, kebanyakkan hari mendapat nilai harian adalah diantara 0 hingga 1. Tetapi bagi lapan hari tersebut, nilai PCI yang diperolehi adalah negatif dimana bekalan berlebihan atau pun banjir telah berlaku. Berasaskan kepada nilai mingguan, hnaya minggu pertama mendapat nilai negatif iaitu -0.44. Pada minggu -minggu lain, nilai berada didalam julat 0.33 higga 0.97. Didapati nilai-nilai WUE dan RWS adalah tinggi berbanding dengan nilai-nilai PCI dan EWUI. Walau bagaimana pun, kesemua indek menunjukkan petak tersebut telah pun diairkan secara terlampau. Ini menunjukkan indek-indek yang dicadangkan memberi keputusan yang memuaskan dan sumbangan mereka pada pengurusan air boleh dipertimbangkan. Banyak analysis dan penyelidikan yang terperinci perlu dilakukan untuk memperakui penggunaan indek-indek tersebut.

CHAPTER I

INTRODUCTION

Irrigation, dubbed the engine of agricultural development in many parts of the world is of major importance. It is important in terms of agricultural production and food supply, the incomes of rural people, public investment for rural development, and often is a recurrent public expenditure for the agricultural sector. However the performance of irrigation in developing countries is not satisfactory. Despite the promise as the engine of agricultural growth, irrigation projects typically perform far below their potential capabilities.

This situation has resulted in many attempts to improve irrigation performance. Many research efforts have been designed to evaluate the effects of such interventions, and to enhance the understanding of the determinants pertinent to performance evaluation so that new approaches for improvement might be developed. Interventions have included physical infrastructures as well as management changes. Managerial changes generally focused on the introduction of a set of 'improved' practices for operating individual irrigation schemes. Physical changes have included such things as linings of canals, installation of measuring and regulating devices and comprehensive rehabilitation programs.

The evaluation of irrigation performance had been greatly emphasised mainly on a particular irrigation sub-system, e.g. a delivery subsystem or the overall project performance. These evaluations usually focus in managing the available resources more efficiently. Unfortunately little attention had been paid in evaluating the performance in an irrigated paddy field plot. Thus the necessity to find relevant indices.

Objectives and Scope of Work

The main objective is to establish indicators that are suitable at field level, and to establish benchmarks that are necessary for performance comparison between different areas. Indices will be developed from these indicators.

The second objective is to study the water balance in a plot with respect to the method of irrigation being practiced by the farmer. This implies that no intervention will be done with regards to the irrigation method being practiced by the farmer. This is important as this will give the actual representation of the water management in that area. All the components of the water balance method will be measured. This is possible as sufficient equipment are available for measuring correctly the amount of rainfall, irrigation, drainage and water storage level within the field plot.

The data from the study will be used to calculate both the conventional and proposed indices. The results will then be compared. Comparing the results will give an overview on the performance of the proposed indices against the conventional indices. This will be the third objective.

As this study is limited to the tertiary field plot level, it is not intended for application to the whole Kerian Irrigation Scheme. However results from this study can be used as a basis for research on an entire project basis.

CHAPTER II

LITERATURE REVIEW

Paddy Production

Importance of Irrigation in Paddy Production

Double cropping of paddy was first introduced into Malaysia in 1942 and with the attainment of independence in 1957, the government initiated a program to increase paddy production with the target of self-sufficiency. Non-photoperiodic-sensitive varieties were introduced and large investments were made to extend and improve irrigation infrastructure. These resulted in a tremendous increase in paddy production in 1980 (Tan, 1987).

There are two ways that irrigation can contribute to the increase of annual paddy production (directly and indirectly) without considering agricultural inputs. First, through the by increase of the area under cultivation and secondly with the availability of water, cropping can be done in the off season thus increases paddy production.

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Research has shown that different water regimes at critical stages like panicle initiation and grain filling stages of growth can affect yield.

Increasing production by area extension is limited as there are competition for land by industries and real estates. Competition of water by industries also contribute to this limitation. Thus paddy production can be improve through efficient water management and adopting modern cultivation practices (Jahirul and Mondel, 1992 ; Jensen et al., 1993).

Irrigation Requirement

Paddy, the staple food crops of Asian countries is a semiaquatic species and with most ecotypes, grows and yields best in submerged "wet paddy" conditions. Although this cultural system demands a high water requirement, its efficacy in obtaining high yields and deriving maximum benefits from other costly inputs is well documented (Tomar and O'Toole, 1980). A significant part of irrigation water in tropical Asia goes to paddy production because it is widely cultivated and water is needed almost through out the planting season. The efficiency of on farm use may average as low as 30% in areas that are well supplied with water (Kampen, 1970). About 70% of the area planted in tropical Asia are rainfed and because of the nature of monsoon rainfall distribution, rainfed paddy production may experience periods of water excess or deficit. Thus the vast irrigated and rainfed paddy growing regions of tropical Asia, with low water use efficiencies illustrate the potential for improved water management on an unparalleled scale (Tomar and O'Toole, 1980).

A fundamental part in improving water management in paddy is an understanding of the irrigation requirement. Irrigation requirement emphasised as the amount of water supplied to meet the Crop Water Requirement (CWR) and the cultural practices for paddy cultivation. Doorenbos and Pruitt (1977) defined CWR as "the depth of water needed to meet the water loss through evapotranspiration (Et) as a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment". In lowland paddy production, the need for 10 cm water depth in the field throughout most of the growing period is mainly for weed suppression and can be viewed as cultural practice. In paddy cultivation, a significant amount of water is " lost " through seepage and percolation. Percolation is defined as the vertical flow of water into the soil and seepage is defined as the horizontal movement of water through the bunds and is not beneficial in paddy cultivation. Opinions differ as to whether this should be considered as a requirement for crop production (Bird and Gillot, 1992). Percolation influences paddy growth and yield in many ways and are mentioned below (Yamazaki, 1987).

a) Quantity of dissolved oxygen, which is brought down into plough layer by percolation of irrigated water,

b) The relation between ammonia requirement of paddy and the quantity and density of ammonia which is brought into plow layer by percolation during paddy growing period,

c) Elimination of iron oxide by percolation,

d) Decrease of organic nitrogen and soil fertility by percolation,

e) Dilution and elimination of toxic materials in plow layer by percolation,

f) Soil temperature fluctuation by percolation.

In reality it is difficulty to measure seepage and percolation separately and thus most researchers had treated them as Seepage and Percolation (S&P). According to Van De Goor and Zilstra (1977), the paddy soils in Malaysia can be grouped into two types, the marine clays and the alluvial clay. In both types, an impermeable layer develops just below the mud layer at the soil surface. This impermeable layer is well developed in the alluvial clay but generally thin in the in the marine clay. In field experiment and field observation, percolation is negligible.

There are two types of paddy cultivation methods. First is the traditional labour extensive method where the seedlings is prepared in a nursery and then transplanted into prepared fields. The second method is the direct seeding where pre soaked seeds are broadcasted directly into prepared fields. The seeds are left to germinate in the damp soil in the field. Water is only supplied after the paddy had established root system.

The volume of water needed for irrigation can be calculated using a water balance method which is a method of accounting volume of water held within a system (Ramlee, 1992). Water balance equation within a system can be expressed in various forms.

The water balance of a paddy field over a season may be written as;

$$P + I = EV + TS + R + L \qquad [1]$$

(Brown, Turner, Thomas et al. 1977)

Where:

P = Precipitation

I = Depth of irrigation

EV= Water lost to evaporation from water surface

TS = Loss due to transpiration

R = Loss by runoff

L = Percolation

Van Der Lelij and Talsma (1976) expressed water balance equation for paddy fields in a semiarid region in Australia as;

$$Fi + R + \Delta S - Fo - I = Er \quad [2]$$

Where;

Fi = Surface inflow

Fo = Outflow

ΔS = Changes in pond levels (positive when increase)

R = Rainfall

I = Seepage or infiltration beyond the rootzone.

Odhiambo and Murthy (1996a) expressed a generalised water balance equation for a single lowland paddy field as;

$$WD_J = WD_{J-1} + RF_J + IR_J - ET_J - SP_J - DR_J \quad [3]$$

Where;

WD = Water depth in the field

RF = Rainfall reaching the field surface

ET = Crop evapotranspiration

SP = Mean seepage and percolation

IR = Irrigation

DR = Surface drainage

j = Time period considered in 1 day unless stated.

It can be concluded that the expression of water balance depends on the researches timeframe and the type of irrigation practiced. Ramlee (1992) in his research on irrigated paddy plot used an equation that was used in this study:

$$IR + RF = ET + (S\&P) + DR + \Delta S \qquad [4]$$

Where;

ET = Evapotranspiration

S&P = Seepage and Percolation

DR = Surface Drainage

RF = Rainfall

IR = Irrigation

ΔS = Variation of the depth of water depth in the field

Water Management

An irrigation system can be made up of three subsystems (Small and Svendensen, 1992). These are i) acquisition subsystem ii) distribution subsystem and iii) application subsystem. The agency manning the project is usually responsible for the first two subsystems. Its primary concern is the delivery of water to the farmers via the tertiary inlets and this is done by supplying water throughout the season, which is true in this study area. The farmers are usually responsible on the application side. If rotational irrigation is practiced by the agency, farmers will store as much water as possible until the next irrigation. Where water is supplied throughout the season, it is unlikely farmers will see the benefit of adopting water management. After seedlings have established, irrigation may commence. There is a tendency to irrigate continuously until maturity.

The aim of agency does not change but their strategy will. The change of strategy is caused by the decreasing availability of recourses. If the resources were to be abundant, they will supply water continuously. Under dire consequences, they would limit their supply to the farmers. It is possible that they would implement guidelines to the farmers or farmer organizations. The farmers on the other hand assume that the agency is responsible to ensure the reliability of water and that they may be unwilling to follow the guidelines and hence the conflict of interest between the farmers and the agency. This is understandable as their livelihood is at stake. Rydzewski (1992) had thoughtfully put this lack of attention in his paper, "Their interest may not be confine to irrigation, but included rained agriculture, animal husbandry, aquaculture, as well as off farm work. To the small farmer the overriding objective is one of security, i.e. reduction of risk. The conservative frame of mind that this encourages is often misunderstood by outsiders: for people living at the margin of subsistence, adopting an innovation that fail may be a matter of life or death".

One other problem that seemed to be of interest to the local agency and researchers is the problem of non-adherence to schedule. Daud et al. (1992) pointed out this problem in their article. They stated that "due to the inefficiency in water management, the off-season transplanting activity in 19,000 ha continuous and plot-to-plot was carried out up to a period of four months after the start of irrigation even though paddy transplanting was scheduled to be completed within 50 days from the start of irrigation". However one cannot discount that the delay in planting can also be caused by external factors. Assessment should be first made in establishing the relationship between land preparation and the size of the project. Insufficient machinery for land preparation in large schemes may be the cause of the delay.

Irrigation Performance Indices

Several researchers had put forward several indicators of performance both quantitative and qualitatively. Most of the indicators were only available to evaluate the performance for the whole irrigation scheme while others can be adopted at the field level.

Molden and Gates (1990) stress the necessity to separate the structural and management components of water delivery system to evaluate their contribution to the overall performance of the system itself. They argued that this system is limited in its capacity for water control by its structural and management characteristic. If either the management or the structural characteristic does not function properly, the whole system performance suffers. They used four criteria in their evaluation namely, adequacy (delivery of required amount), efficiency (conservation of water resources), dependability (uniform delivery over time) and equity (delivery of fair amount). Twenty-three indices were used for all the criteria and the variables may be