UNIVERSITI PUTRA MALAYSIA

AN EXPERT SYSTEM FOR PREDICTING DISTRIBUTION AND CONSUMPTION OF IRRIGATION WATER IN A PADDY IRRIGATION SCHEME

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By

MOHAMED BIN DAUD

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This dissertation is dedicated to the author's beloved wife and associate;

Tengku Azemah T Abdullah

and their six children;

Nik Nur Eliza
Nik Nur Eniza
Nik Mohamed Mohaz
Nik Nur Sukma
Nik Mohamed Moriz
Nik Mohamed Arif

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LIST OF ABBREVIATIONS

ES	Expert System
AI	Artificial Intelligence
ISU	Irrigation Service Unit
ET	Evapotranspiration
KADA	Kemubu Agricultural Development Authority
SOGREAH	Societe Grenobloise d'Etudes et d'Applicate Hydraulique
D1	The week when transplanting in an ISU actually started
D2	The week when 50% of an ISU had actually been transplanted
D3	The number of weeks (duration) required to complete transplanting 50% of the area of an ISU
JY	The percentage area of an ISU that was transplanted at the end of the season
SAS	A computer statistical analysis package
Lc	Length of the field canal connecting an ISU and the respective field offtake
A	Size of an ISU in hectare
W	Maximum width of an ISU in meter
L	Length of an ISU in meter
S	Slope of an ISU in percent
R	Degree of rectangularity of an ISU. R is determined by dividing the ISU size with the product of (W x L).
DH	The difference in elevation between the point where water enters an ISU and the furthest downstream point in the unit.
MAIN	Independent variable to represent the main sub-systems
CAT	Independent variable to represent the category of a canal

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Chairman: Assoc. Prof. Dr. Salim Said

Faculty: Engineering

PADI_EX (Paddy Irrigation Expert), an expert system (ES) to predict the state of irrigation water distribution and consumption at an Irrigation Service Unit (ISU) level during off-season planting in a paddy irrigation scheme with double cropping was developed through a combination of interviews with field experts and formal field research. The purpose of the interviews was to identify and describe the problem domains and get the experts' opinions on the problems that would be studied at field level in order to translate the experts' knowledge into a more numerical form or specific rules that could then be incorporated into the ES. The raw data of the field studies were stored in databases and can be updated and referred to through the ES. The possible roles for PADI_EX are as advisor and peer system for better water management in a continuous and plot-to-plot paddy irrigation scheme.

Abstrak dissertasi yang dikemukakan kepada Senat Universiti Pertanian Malaysia untuk memenuhi syarat untuk mendapatkan ijazah Doktor Falsafah.

SISTEM PAKAR UNTUK MERAMAL DAN MENILAI TAHAP PENYEBARAN DAN PENGGUNAAN AIR PENGAIRAN DALAM SEBUAH PENGAIRAN PADI

Oleh

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PADI_EX (Paddy Irrigation Expert), satu sistem pakar (ES) yang boleh meramal dan menilai tahap penyebaran dan penggunaan air pengairan pada peringkat unit pengairan (ISU) semasa penanaman padi luar musim di sekim pengairan yang memperaktiskan penanaman padi dua kali setahun dihasilkan melalui gabungan di antara temubual dengan pakar-pakar dan kajian ladang. Tujuan temubual dengan pakar-pakar adalah untuk menentukan dan menerangkan tahap permasaalahan yang seterusnya akan dikaji pada peringkat ladang supaya kepakaran ini dapat dinyatakan dalam bentuk yang lebih numerik dan berbentuk undang-undang khusus yang boleh dimasukkan ke dalam sistem pakar yang akan dihasilkan. Data kajian ladang akan disimpan di dalam pangkalan data yang kemudiannya boleh dikemaskini dan dirujuk melalui ES. Tugas yang mungkin dijalankan oleh PADI_EX adalah sebagai penasihat dan saling membantu dengan pihak pengurusan untuk mengurus sekim pengairan petak ke petak yang dibekali air secara berterusan.

CHAPTER I

INTRODUCTION

Double cropping of paddy is an activity which uses plenty of water. The general contention in South and Southeast Asia is that the performance of irrigation systems is far below expectation (Garces, 1983). Various studies (Kampen, 1970; Wickham and Valero, 1979; Yashima, 1987) have shown that there are some agreements with this contention. The studies also suggest that on the average water consumption efficiency in a rice field is less than 30%.

In paddy irrigation, more than half of the water supplied is used for presaturation; i.e to presaturate and inundate fields before planting of crops. This presaturation water is not consumed by the rice plant. The longer it takes to supply this amount of water the more water would be lost through percolation, evaporation, and mostly through surface drainage.

Reducing the presaturation period may lead to water saving. For that reason, during presaturation period the system should deliver at maximum capacity in order to reach all the fields as fast as possible so that planting of rice could be done without delay. But in the actual situation, by increasing the irrigation rate alone, transplanting for the entire scheme cannot be speeded up much, because among other reasons, is the inequitable and unreliable water distribution to the various parts of the scheme.

The efficiency of water distribution and eventually consumption within an irrigation scheme is due to many factors, such as the layout of a canal system, the conditions of paddy fields, and farmers' behaviour towards irrigation water supply.

The extent of the contributions of each of these factors is very hard to quantify. Without a clear quantifiable relationship, mathematical and statistical models to explain the source of inefficiency are very difficult to produce. For that an expert system is thought to be more appropriate. An expert system is efficient and fast in continuous updating and extracting large data bases. It could also be used as a decision making tool in improving water management in irrigation schemes.

Statement of the Problems

This study was conducted in Kemubu paddy irrigation scheme situated on the eastern bank of Kelantan river, on the east coast of Peninsular Malaysia. Paddy land constitutes approximately 50% of the 37,744 ha land located within the scheme boundary. Records for the scheme have shown that the percentage of planted paddy area was persistently very low. Every season only slightly more than half of the paddy area was managed to be planted at the end of a season. The failure to adhere to the gazetted schedule was more serious for the off-season planting. The crop for a new season cannot be started prior to the harvesting of the previous season's crop.

As the result of the schedule non-adherence, paddy planting cannot take full advantage of the rainfall during the planting cycle. Too long a delay in transplanting activity will result in parts of the scheme not being planted with paddy because newly transplanted paddy plants cannot withstand the incoming northeast monsoon period, when from the month of September to December the scheme receives too much rainfall. Hence, there is an urgent need to improve water distribution efficiency in the scheme.

Research Objectives

The objective of the research is to discover a relationship between the design parameters and operational aspects of an irrigation system with regards to the problem of low percentage of planted area and schedule non-adherence in the paddy irrigation scheme and subsequently to produce an expert system (ES) that could be used as a decision-making tool by the scheme managers and engineers to improve water distribution and consumption efficiency.

The specific objectives of this research are;

(i) To extract knowledge from selected field experts on main problems related to the inefficiency of water distribution and consumption in the scheme. The experts would also be asked to suggest the probable causes and solutions to the problems.

(ii) To conduct a field research in order to translate the knowledge derived from the meetings with the field experts into a form that could be used by the expert system (ES) to be developed.

(iii) To develop an expert system (ES). The rules for the ES are developed through a combination of field experts' opinions and the field study. Related information on canal system, field gate flow, size and shape of irrigation units within the scheme shall be incorporated into the ES to be used as a reference by the scheme managers and engineers.

Scope and Limitations

Only the design and operational aspects of the irrigation scheme would be considered in this study. Social factors that could also affect the distribution and consumption of irrigation water in this paddy irrigation scheme would not be considered.

The study was conducted during an off-season planting. As such, the expert system developed could only be used to predict distribution and consumption of irrigation water in Kemubu irrigation scheme during an off-season planting. During the main season planting, with the scheme receiving heavy rainfall, there is no shortage of water; hence the efficiency of distribution and consumption of irrigation water is not critical.

The expert system (ES) developed is meant to be used by the managers and engineers of Kemubu scheme in order to improve the efficiency of distribution and consumption of irrigation water in the scheme. Additional research is required if the ES is to be adopted for other irrigation schemes.

Outcome of the Research

The outcome of this research is an ES that can be used for predicting distribution and consumption of irrigation water in the Kemubu paddy irrigation scheme. As such it is envisaged that the ES would become a very useful decision-making tool for a better irrigation water management.

CHAPTER II

LITERATURE REVIEW

In Malaysia, with the introduction of irrigation schemes, paddy can be planted twice a year on a large scale. Double cropping of rice in Malaysia started in 1942 with the introduction of the Japonica varieties. Response was very localized and it was not until the 1960s when locally developed varieties were introduced together with irrigation facilities and relevant support programs that it gained momentum to reach 284,000 ha, or 90% of the irrigated area by 1985 (Tan Jin Tun, 1987; Jegatheesan, 1987). The off-season crop can give a higher yield if irrigation water is available. The yields can be at least 50% higher in the dry season than in the wet season because of higher solar radiation (De Datta, 1981).

Irrigation of paddy plots in the Kelantan delta, where the present Kemubu irrigation scheme is located was already documented way back in 1908. Graham (reported by Hill, 1977), described that in the Kelantan delta there was a prominent type of rice land called *tanah cedong*. The *tanah cedong* was a land for transplanting, upon which standing water, supplied either by irrigation or by rainfall, was maintained within low embankments during the greater part of the time the crop was in the ground. This class of land was planted annually.

Studies of water requirements for rice with supplemental irrigation suggest that water consumption efficiency is as low as 30% in areas that are well supplied with water (Kampen, 1970). The low water consumption efficiencies of these systems indicate the need for improved water management. Since irrigated areas account for 50% of the world rice harvest (De Datta, 1981), improved water consumption has the potential to significantly increase production.

Water Requirement

In order to produce optimum yields of rice, enough water must be supplied to satisfy the evapotranspiration needs of the crop and losses from the paddy areas and to submerge the soil for weed control purposes. Timely water supply is equally important for optimum growth and high grain yield of rice. Total water requirement includes water needed to raise seedlings, prepare land, and to grow a crop of rice from transplanting to harvest.

Evaporation from the soil and water surfaces and transpiration from the plant leaves are combined and treated together as evapotranspiration (ET). ET for rice depends mostly on climatic conditions (Wickham and Sen, 1978). In most of the tropics, the ET during the wet season is 4-5 mm/day. During the dry season, the ET value can be between 6-7 mm/day for large irrigated areas.

Various studies suggest that the range of percolation varies between wide limits from less than 1 mm/day in compact soil to several hundred millimeters per day in loose soil (Anyoji and Thavaraj, 1987; Fujio Yamazaki, 1988; Hukkeri and Sharma, 1980). Percolation rate of 10-15 mm/day is suggested to be favourable for supply of dissolved oxygen, the removal of harmful substances, and the maintenance of root activity. Sharma and De Datta (1992) concluded that under tropical conditions, percolation may benefit rice yield in soils having high organic matter content. In other soils, higher percolation rates aggravate leaching losses of nutrients and lower water-use efficiency.

There are two kinds of seepage losses; i.e. perimeter seepage and levee seepage. Perimeter seepage is that water moving from a rice-growing area into a creek or areas not planted with rice, and is therefore considered a water loss. Levee seepage is the lateral subsurface movement of water within a rice-growing area, and is not a loss except where it occurs through the last levee (bund) separating the field from a drain (De Datta, 1981; Walker and Rushton, 1986).

According to a study (Kitamura, 1987), during supplementary period of the off-season paddy irrigation, the water lost through perimeter seepage accounted for 4.4 mm/day or 41.5% of the 10.6 mm/day average daily water consumption.

Water Consumption

Water consumption can be classified as:

(i) For presaturation,

(ii) Maintenance water.

Water for Presaturation

Presaturation is defined as the amount of water required to soak the soil, flood the field surface and supplement the water loss due to evaporation, seepage and percolation until paddy is transplanted in the plot (Yashima, 1984).

According to some researchers, presaturation period for an area is not just the number of days required to presaturate the area but is also associated with planting progress. In calculations, the presaturation period is usually taken as from the beginning of the irrigation supply to the time when transplanting had been completed in 50% of the area (Miranda and Levine, 1979; Yashima, 1984).

Presaturation requires a large amount of water per unit time (Lucero, 1984). The amount of water needed depends mainly on soil type and water holding capacity, but most importantly on type of land preparation (De Datta, 1981). The longer the presaturation period, the more would be the total amount of water used for presaturation, since the total amount of water lost through evapotranspiration and percolation would increase.

Usually about half of the irrigation water used is for presaturation. Kung (1971) suggested that 200 mm of water is commonly used for presaturation. However, the amount of water required varies from 100 mm to 300 mm (Lucero, 1984). It varies from country to country; for example, 130 mm in Japan and 420 mm in Surinam (Kampen, 1970). The Royal Department of Irrigation in Thailand used values ranging from 144 to 200 mm.

The results from a research in the Philippines (Wickham and Sen, 1978) showed that 656 mm was used for the 48-day presaturation period; Land soaking used 110 mm of water. Seepage and percolation losses were 396 mm. Another 150 mm was lost through surface evaporation. Another research in Malaysia (Yashima, 1987) showed that more water (997 mm) was used for a longer presaturation period (57 days).

The higher the rate of flow into an irrigation service unit (ISU), the easier it will be to presaturate the unit.

Also it will be easier to presaturate the first part of a unit than the remainder part of the unit (Kitamura, 1987). For presaturation, rain fall is four times more effective than irrigation water since rainfall brings water directly to the paddy fields without any time lag (Yashima, 1984). If the presaturation period falls during a dry period, irrigation water requirement is very high.

Miranda and Levine (1979) concluded that the size of the command area did not influence the presaturation period. It was also concluded that the duration of the process was shortest in areas of simultaneous delivery supply and longest in those of lateral (emergency rotation), possibly because more water was available to the areas served by simultaneous distribution.

In designing the conveyance network of an irrigation scheme and water duty at the field gate, it is important to consider the presaturation period and the amount of water required for the period since the peak water demand will coincide with the presaturation period (Daud et al., 1992a). Spare et al. (1980), Suryavanshi and Mohan (1986), Wang and Hagan (1977), Van de Goor and Zijlstra (1968) and Shiraishi (1986) discussed several formulas to determine the peak demand for canal sizing and discharge required during this period.