INTEGRATED WATER MANAGEMENT DECISION SUPPORT SYSTEM FOR SEBERANG PERAK PADDY ESTATE

By

MOHAMED MUJITHABA MOHAMED NAJIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Dedicated to the author's Mother Mrs. M.H. Fathuma, and Father Mr. A.W.M. Mujithaba

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: Associate Professor Lee Teang Shui, Ph.D.

Faculty: Engineering

A study was carried out to develop an integrated water management decision support system for the Seberang Perak paddy estate. The decision support system incorporated results from a database management system, a model base management system and a rule based knowledge base system.

The domain experts' knowledge on integrated water management were collected together with other secondary historical data that were used in the modeling approach to generate more knowledge on different combinations of possible scenarios. The modeling approaches used in the knowledge generation was evapotranspiration modeling, a flow routing modeling, a water balance modeling and a crop growth and a yield modeling. A GIS was used in the output model to make the decision support system outputs more effective in their presentation.

The evapotranspiration modeling tested the suitability of a few methods to predict evapotranspiration in the project area using 45 years of weather data.

The results suggested applying the Penman-Monteith, the Pan or the Blaney-Criddle models for the project area seems to be the best. Because of its worldwide applicability, the Penman-Monteith model was utilized in the study.

The flow routing routine performed showed good agreement with measured data. Evapotranspiration estimates, flow routing and water balance applied to each of the field plots for all possible scenarios, suggested alternative decisions for the better performance of the paddy estate. All these results were coded to rules and kept in knowledge bases that will be posted as outputs for user queries.

Major problem identified in the Seberang Perak paddy estate was the land preparation water management. Land preparation needs to be completed within 16 days so that the targeted 250% cropping intensity could be achieved. This is only possible when canals are flowing full and a part of the total water requirements is supplemented with rainfall. The modeling approach suggested many possible alternate scenarios and decision alternatives, which were gathered in the knowledge bases.

The knowledge generated through modeling approach was always verified with domain experts from the sub-estates concerned. The acceptable knowledge were then coded to pseudocodes and translated to rules of the knowledge bases. All the added rules to the knowledge bases were verified and validated for the proper functioning of the decision support system components. All the knowledge-based modules (menu module, crop schedule, land preparation

water management, second supply water management, supply after fertilizer application, yield modeling and drainage management) were linked under a same platform. The outputs and results of these components are linked with a GIS and other relevant information.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SISTEM SOKONGAN BERKEPUTUSAN PENGURUSAN AIR BERSEPADU UNTUK ESTET PADI SEBERANG PERAK

Oleh

MOHAMED MUJITHABA MOHAMED NAJIM

Julai 2004

Pengerusi: Profesor Madya Lee Teang Shui, Ph.D.

Fakulti: Kejuruteraan

Satu kajian telah dibuat demi membangunkan sebuah sistem sokongan berkeputusan pengurusan air bersepadu untuk Estat Padi Seberang Perak. Sistem sokongan berkeputusan mengabungkan keputusan keputusan daripada satu sistem pengurusan pangkalan data, satu sistem pengurusan pangkalan model dan satu sistem pangkalan ilmu berasas petua.

Ilmu pengurusan air bersepadu pakar domain dikumpulkan bersama sama data sejarah sekunder yang diguna untuk pendekatan menjanakan lebih ilmu mengenai kombinasi senario. Pendekatan pemodelan dipakai menjanakan ilmu ialah pemodelan penyejatpeluhan, pemodelan penghalaan aliran, pemodel pengimbangan air dan pemodelan tumbuhan tanaman dan hasil. Satu GIS telah dipakai dalam model pengeluaran demi mempersembahkan secara berkesan hasil sistem sokong berkeptusan.

Pemodelan penyejatpeluhan mengujikan kesesuaian beberapa kaedah untuk meramalkan penyejatpeluhan dikawasan tersebut dengan 45 tahun data cuaca. Berdasar keputusan keputusan diperolehi boleh diusulkan bahawa kaedah Penman-Monteith, Pan atau Blaney-Criddle untuk kawasan projek merupakan yang terbaik. Oleh kerana penggunaannya di seluruh dunia, model Penman-Monteith telah pakaiguna dlam kajian ini.

Rutin penghalaan aliran yang dijalankan telah menunjuk persetujuan dengan data yang diukurkan. Penaksiran penyejatpeluhan, penglaan aliran dan pengimbangan air yang dipakiaguna dalam setiap plot bagi semua senario yang boleh berlaku, telah mengusulkan keputusan keputusan berlainan demi untuk perlaksanaan lebih baik untuk estet padi itu. Semua keputusan telah dikodkan menjadi petua dan disimpan dalam pangkalan limu yang akan dikeluarkan sebagai hasil berasaskan soaltanya pengguna.

Masalah utama yang disahkan di Estet Padi Seberang perak ialah pengurusan air semasa penyediaan tanah. Penyediaan tanah perlu disiapkan dalam 16 minggu semoga 250% intensiti tanaman boleh dicapai. Ini hanya boleh dicapai sekiranya aliran saluran penuh dan sebahagian jumlah keperluan diisikan hujan. Pendekatan model memberi banyak senario pilihan dan pilihan keputusan yang dikandungkan didalam pangkalan olmu.

Ilmu yang dijanakan melalui pendekatan pemodelan sentiasa disahkan oleh pakar domain daripada subestet berkenaan. Ilmu yang boleh diterima kemudian dikodkan dalam psedokod dan diterjemahkan kepada petua petua

pangkalan ilmu. Semua petua yang ditambah kedalam pangkalan imlu telah ditentusahkan dan dinilaikan demi untuk menjamin fungsi komponen komponen sistem sokongan berkeputusan. Semua modul modul (module menu, jadual tanaman, pengurusan air penyediaan tanah, pengurusan air, pengurusan air bekalan kedua.bekalan selepas semburan baja, pemodelan hasil dan pengurusan salira) telah digabungkan dibawah satu platform. Pengeluran dan keputusan komponen komponen digabungkan dengan GIS dan maklumat lain yang bersabit

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I certify that an Examination Committee met on 8 July 2004 to conduct the final examination of Mohamed Mujithaba Mohamed Najim on his Doctor of Philosophy thesis entitled "Integrated Water Management Decision Support System for Seberang Perak Paddy Estate" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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MOHAMED MUJITHABA MOHAMED NAJIM

Date:

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LIST OF ABBREVIATIONS

ρ_a	air density
$(e_a - e_d)$	vapor pressure deficit
A	flow cross-sectional area
AEGIS	Agricultural and Environmental Geographic Information System
AGNPS	AGricultural Non-Point Source
AI	Artificial Intelligence
ANSWERS	Aerial Non-point Source Watershed Environment Response Simulation
A_{pt}	rice area under land preparation during time period t
A_{st}	rice area under soaking during time period t
BERNAS	National Paddy and Rice Authority
CanalMan	Canal Management Software
C_p	specific heat of the air at constant pressure
CropSyst	Cropping Systems Simulation Model
D	Day
DID	Department of Irrigation and Drainage
DMIS	Decision support system for the management of the irrigation schedule
DOA	Department of Agriculture
dp	depth of water required for crop submergence
d_r	relative distance Earth – Sun
DR_j	amount of drainage
ds	depth of water required to saturate the soil
DSS	Decision support system
DSSAT	Decision Support System for Agrotechnology Transfer
e_a	saturation vapor pressure
$e_a(T)$	saturation vapor pressure at temperature T
$e_a(T_{max})$	saturation vapour pressure at T_{max}
$e_a(T_{min})$	saturation vapour pressure at T_{min}
e_d	actual vapor pressure
E	evaporation rate
E_{pan}	Pan-evaporation
ERF_t	effective rainfall during time period t
ET_j	crop evapotranspiration
ET_o	reference crop evapotranspiration
E_u	irrigation efficiency
EXPERDI	Computerized System for the Distribution of Water in Irrigation Modules
FAO	Food and Agriculture Organization
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FOA	Farmer Organization Authority
F_r	Froude number
FSL	Full supply Level
g	ratio of weight to mass
G	soil heat flux
GIS	Geographical Information System
GRASS	Geographic Resources Analysis Support System
h	flow depth

h_c	mean height of the crop
HSPF	Hydrology Simulation Procedure - FORTRAN model
IFCC	Improved Field Capacity Concept
IMSOP	Irrigation Main System OPeration model
INCA	Irrigation Network Control and Analysis software
IPM	Integrated Pest Management
IR_j	amount of irrigation water applied
IRRI	International Rice Research Institute
ISM	Irrigation Scheduling Model
j	time period in days
J	number of the day in the year
JICA	Japan International Cooperation Agency
K	Potassium
K_p	Pan coefficient
L	leaf area index
LBC	Left Branch Canal
LPRF	rainfall during land preparation period
M	Month
MARDI	Malaysian Agricultural Research and Development Institute
MMS	Malaysian Meteorological Services
MUDA	Muda Agricultural Development Authority
n	actual duration of sunshine
N	maximum possible duration of sunshine or daylight hours
n/N	relative sunshine fraction
NIR	net irrigation requirement
NIR_{it}	irrigation requirement of rice during time period t
NPS	non-point source
NuDSS	Nutrient Decision Support System
OMIS	Operational Management of Irrigation Systems
OR_{it}	irrigation requirement of offtake i during time period t
P	atmospheric pressure
PEsIDS	Paddy Estate Integrated water management Decision Support system
PRF	rainfall during prior period
p_{rt}	land preparation requirement during time period t
Q	flow rate
r_a	aerodynamic resistance
R_a	extraterrestrial radiation
RBC	Right Branch Canal
r_c	vegetation canopy resistance to water vapor transfer
RF_j	rainfall received during jth day
RH	Relative Humidity
RH_{max}	maximum daily relative humidity
RH_{min}	minimum daily relative humidity
R_n	net radiation at crop surface
R_{nl}	net outgoing long-wave radiation
R_{ns}	net incoming short-wave radiation
RO_j	surface runoff
RP	required ponding depth
r_{st}	land soaking requirement during time period t

SDSSs	**Spatial decision support systems**
S_f	**energy loss gradient**
SIMRIW	**Simulation Model for Rice-Weather Relationship**
S_{max}	**Maximum allowable water levels**
S_{min}	**Minimum allowable water levels**
S_o	**longitudinal bed slope**
SP	**seepage and percolation rate**
SP_j	**amount of seepage and percolation loss**
T	**air temperature**
t	**elapsed time**
T_{max}	**maximum daily temperature**
$T_{max.k}$	**maximum temperature [K]**
T_{min}	**minimum daily temperature**
$T_{min.k}$	**minimum temperature [K]**
tp	**time required to land preparation**
ts	**time required to saturate the soil**
U_2	**wind speed measured at 2 m height**
U_z	**wind speed measurement at height z**
V_a	**volume of water supplied to the plot per day**
V_{nr}	**net volume of water requirement in a plot per day**
WADPRO	**Water Allocation and Distribution Program**
WD_j	**water ponding depth in the field on the jth day**
WD_{j-1}	**water ponding depth in the field on the (j-1)th day**
x	**longitudinal distance in the direction of flow**
z	**height at which meteorological variables are measured**
Z	**seepage loss term**
z_o	**aerodynamic roughness of the surface**
γ	**psychrometric constant**
Δ	**slope of the vapor pressure curve**
δ	**solar declination**
λ	**latent heat of vaporization**
φ	**latitude**
ω_s	**sunset hour angle**
ΔS	**Storage**
Δ**t**	**computational time step**
Δ**x**	**spatial increment in the direction of flow**
ϕ	**spatial weighting factor**
θ	**temporal weighing factor**