DECISION SUPPORT SYSTEM FOR WATER MANAGEMENT IN THE BESUT RICE IRRIGATION SCHEME

By

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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 heartfelt loving mother and wife

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

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A decision support system (DSS) model was developed to improve decision-making with respect to water release schedules and timely water distribution in a large double cropping rice irrigation scheme. The model focuses mainly on water allocation decisions and timely water distribution. The DSS model includes data management, model management, a knowledge base and a user interface. Data management and model management systems are external to the DSS. The data management system is composed of the following subsystems: meteorological data, hydrological data, irrigation canal data, soil data and crop data. Four mathematical models; crop water, stochastic rainfall, canal simulation and water balance models were developed for the model management system.

The Penman-Monteith method was applied for estimating reference evapotranspiration. Then the crop water model was developed from reference evapotranspiration and crop coefficient. Evapotranspiration was found to be 4.20

mm/day and 3.99 mm/day for off season and main season crop respectively. Crop evapotranspiration was higher during the off season crop compared to that of the main season crop, mainly as a result of prevailing weather conditions. A stochastic rainfall model was developed using 30 years daily rainfall data from six stations. A first order Markov chain was used to simulate the occurrence of rainfall, and a skewed normal distribution was applied to fit the amount of rainfall for a rainy day. The stochastic rainfall model verification was performed with a separate set of data. Results obtained showed that the model could be used to generate rainfall data in the area satisfactorily.

A water balance model was utilized to determine irrigation water requirements. It was observed that a modification of the existing irrigation schedules would have saved a considerable amount of irrigation water during the main season and off season. Based on field water requirements during the pre-saturation and normal irrigation supply periods and available flows at the intake structures, canal simulation was performed using the CanalMan model. Results have shown that pre-saturation should not be done continuously unless flow rates are at least 9.00 m^3/sec and 3.00 m^3/sec at the Besut and Angga intake gates respectively. If the flow rates fall below these values, then pre-saturation should be done in two stages. However, when the flow rate is between 5.00 and 5.65 m^3/sec at the Besut intake, pre-saturation should be done over three stages. During the normal irrigation supply period, flow rates of 5.00 m^3/sec and 1.50 m^3/sec at the Besut and Angga intake gates respectively, are to be maintained for the whole irrigation scheme. Otherwise selective irrigation or irrigation on a rotational basis has to be adopted.

The knowledge base for the DSS was developed from the knowledge derived from domain experts as well as the results from the model management system. The models were used to extract knowledge related to aspects of irrigation water management. The knowledge extracted was checked with domain experts in order to verify the reliability of the knowledge. The knowledge extracted was then added to the final decision support system in the form of rules. The knowledge generated together with the domain experts' knowledge, were compiled with rules and incorporated to the menu driven DSS, developed using the wxCLIPS software. The knowledge base thus created was continually tested for the consistency and appropriateness, and updated during the development stage. The DSS was evaluated to assess its decision-making capability using one-year water management data, which was not used in the development of the DSS. Based on the evaluation, it can be inferred that the DSS developed can be an effective tool for use in decision-making on water management under practical situations.

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

SISTEM SOKONG KEPUTUSAN UNTUK PENGURUSAN AIR DI SKEMA PENGAIRAN PADI BESUT

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Sebuah model sistem sokong keputusan (DSS) telah dibangunkan bagi memperbaiki sistem membuat keputusan berkaitan dengan jadual lepasan air dan pengedaran air pada masa yang tepat untuk satu projek pengairan padi tanaman berganda yang besar. Fokus utama model ialah keputusan peruntukan air dan pengedaran air pada masa yang tepat. Model DSS mengandungi aspek pengurusan data, pengurusan model, satu pangkalan ilmu dan satu antara-muka pengguna. Sistem pengurusan data terdiri daripada subsistem berikut: iaitu data meteorologi, data hidrologi, data saluran pengairan, data tanah dan data tanaman. Empat model matematik; air tanaman, hujan stokastik, penyelakuan terusan dan model pengimbangan air telah dibangunkan untuk sistem model pengurusan.

Kaedah Penman-Monteith telah digunakan untuk menaksirkan penyejatpeluhan rujukan. Kemudian model air tanaman telah dibangunkan daripada penyejatpeluhan dan angkali tanaman. Penyejatpeluhan didapati sebanyak 4.20 mm/hari dan 3.99

mm/hari bagi musim luar dan musim tanaman utama masing masing. Penyejatpeluhan tanaman lebih banyak pada musim tanaman luar dibandingkan dengan pada musim tanaman utama, terutama disebabkan keadaan cuaca semasa yang wujud. Satu model hujan stokastik telah dibentuk berdasarkan data hujan harian sepanjang 30 tahun yang terdapat di enam buah stesyen. Satu rantai Markov bertertib pertama telah digunakan untuk menyelaku berlakunya hujan, dan satu taburan normal pencongan telah digunakan bagi menentukan kuantiti hujan untuk hari yang berhujan. Kepatuhan model hujan stokastik diuji menggunakan set data yang berasingan. Keputusan yang diperolehi menunjukkan bahawa model tersebut boleh diguna untuk menjanakan dengan sempurna, data hujan dalam kawasan itu.

Satu model pengimbangan air digunakan untuk menentukan keperluan air pengairan. Diperhatikan bahawa dengan pengubahsuaian kepada jadual pengairan kini kuantiti air pengairan boleh dijimatkan pada musim utama dan musim luar. Selain daripada itu, berasaskan keperluan air pada jangkamasa pra-ketepuan dan bekalan biasa serta aliran sumber air yang terdapat di struktur pengambilan, penyelakuan saluran telah dijalankan dengan mengguna model perisian CanalMan. Keputusan telah menunjukkan bahawa penyediaan tanah tidak patut dijalankan secara berterusan kecuali bila ujudnya kadar aliran sumber sekurang-kurangnya 9.00 m^3/saat di Empangan Rendah Besut dan 3.00 m^3/saat di Empangan Rendah Angga. Sekiranya kadar aliran kurang daripada nilai tersebut, maka pra-ketepuan tanah patut dilakukan dalam dua peringkat. Akan tetapi, bila kadar aliran adalah 5.00 hingga 5.65 m^3/saat di Empangan Rendah Besut, kerja pra-ketepuan tanah patut dilakukan dalam tiga peringkat. Pada masa bekalan pengairan biasa, kadar aliran sebanyak 5.00 m^3/saat dan 1.50 m^3/saat di Besut dan Empang Rendah Anggan masing masing, mesti

dikekalkan demi untuk menjamin pengairan kepada keseluruhan skema. Sekiranya tidak, maka pengairan secara pilihan atau pengairan secara berputaran terpaksa diguna.

Pangkalan ilmu untuk DSS tersebut telah dibangunkan berdasarkan ilmu pengetahuan hasil daripada pakar pakar domain selain daripada keputusan sistem model pengurusan. Model-model telah diguna untuk menyari ilmu berkaitan dengan aspek aspek pengurusan air pengairan. Ilmu yang disarikan disemak dengan pakar pakar domain demi untuk menentusahkan kebolehpercayaan ilmu itu. Ilmu yang disarikan ditambah kemudian kepada sistem sokongan keputusan terakhir dalam bentuk petua. Ilmu yang dijanakan bersama-sama pengetahuan pakar domain dikompilasikan dengan petua dan digabungkan kedalam DSS berpandu menu, yang dibangunkan mengguna perisian wxCLIPS. Pangkalan ilmu yang dihasilkan secara berterusan diuji untuk kekonsistenan dan kepadanan, dan dikemasikini semasa peringkat pembangunannya. DSS telah dinilaikan demi untuk menentukan keupayan membuat keputusan dengan menggunakan data pengurusan air setahun, yang mana data ini tidak pernah diguna untuk pembentukan DSS itu. Berdasarkan penilainan, ianya boleh disahkan bahawa DSS yang dibangunkan menjadi satu alat berkesan untuk membuat keputusan praktik mengenai pengurusan air.

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I certify that an Examination Committee met on 17 August 2004 to conduct the final examination of Md. Aminul Haque on his Doctor of Philosophy thesis entitled "Decision Support System for Water Management in The Besut Rice Irrigation Scheme" 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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