UNIVERSITI PUTRA MALAYSIA

ESTIMATION OF RICE EVAPOTRANSPIRATION IN PADDY FIELDS USING REMOTE SENSING AND FIELD MEASUREMENTS

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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

December 2005

Dedication

To my wife, Fairouz, my son Ahmed and my Family, with your love and support, I have accomplished one of my goals

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

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Chairman: **Associate Professor Abdul Rashid Mohamed Shariff, PhD**

Faculty: **Engineering**

Water resources are limited in many parts of the world. Due to the fast growing world population, the demand for domestic and industrial water use is increasing tremendously. This results in reduction of water for agricultural use, especially for major rice growing areas which needs huge amounts of water. The study was carried out in the northwest of Selangor, in the Tanjung Karang Rice Irrigation Project Malaysia. The objectives of this study were to estimate the rice evapotranspiration using satellite data and compare it with the field measurements. Eight sets of non-weighing lysimeters (91 cm x 91 cm x 61 cm) with attached casella hook were installed to measure the crop evapotranspiration at five different locations within the 19000 ha rice irrigation scheme. Global positioning system (GPS) was used to locate the lysimeter position. The rice yields in the lysimeters were manually measured for three seasons. An automatic meteorological station was installed inside the field to collect data required for calculations of the crop evapotranspiration using the CROPWAT software. NOAA satellite data was used as data input to correlate the remote sensing data with field evapotranspiration data. For three seasons, the off (dry)

season from December to May, the main (wet) season from July to November, the observed ET from the lysimeters ranged from 3.2 to 5.8 mm/day, while ET by calculation using weather parameters ranged from 3.15 to 5.72 mm/day. There was no significant difference between the blocks in the first season of the experiment because of the small area and not much difference in the environmental conditions within the block. Most of the correlation for the second and the third season were significant at 0.01%. The corresponding ET values from satellite data were 4.04 to 6.54 mm/day. Considering ET measured by lysimeter as the most accurate method, ET determined using satellite data overestimates and by computed method underestimates those obtained by lysimeter. ETc by NOAA data were found to overestimate by 8% to 12% with an average of 10%. Using CROPWAT, ETc were found to be underestimated between 7% and 20% with an average of 14%.

The significance findings of this research are that ET can be estimated for paddy areas in Malaysia with reasonable accuracy using satellite data or computed method. The implications are that much time and cost can be saved using these alternative techniques compared to manual data collection from lysimeters. This will result more efficient water management planning in the rice areas.

Generally, by knowing the actual ET, the cropping calendar can be prepared at the beginning of the cultivation season by knowing the amounts of water needed throughout the season.

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

PANGGARAN PENYEJATPELUHAN PADI DI SAWAH MENGGUNAKAN KAEDAH PENDERIAN JAUH DAN PENGUKURAN DI LAPANGAN

Oleh

HASSAN SAAD MOHAMMED HILMI

Disember 2005

Pengerusi: **Profesor Madya Abdul Rashid Mohamed Shariff, PhD**

Fakulti: **Kejuruteraan**

Sumber air sangat terhad di kebanyakkan tempat di dunia. Populasi dunia yang semakin bertambah menyebabkan permintaan bagi kegunaan air dalam negeri dan industri meningkat secara mendadak. Keadaan ini menyebabkan penggunaan air untuk pertanian berkurangan terutamanya di kawasan penting penanaman padi. Kajian ini telah dijalankan di bahagian barat-laut Selangor iaitu kawasan projek Pengairan Padi Tanjung Karang. Objektif kajian ini ialah untuk menganggar sejatantranspirasi padi menggunakan data satelit dan menbandingkannya dengan ukuran yang di dapati di bendang. Lapan set lysimeter yang tidak menimbang berukuran (91cm x 91cm x 61cm) bersama cangkuk 'casella' di pasang untuk mengukur sejatantranspirasi padi pada lima bahagian tempat di kawasan rancangan pengairan yang berukuran 19000 hektar. Sistem penentu kedudukan global (GPS) digunakan untuk melokasikan kedudukan lysimeter. Hasil padi diukur secara manual untuk tiga musim. Stesen 'cuaca' automatik dipasang dalam bendang untuk mengumpul data yang diperlukan bagi mengira sejatantranspirasi tanaman

menggunakan perisian 'CROPWAT'. Data satelit "NOAA' digunakan sebagai data ke masukan untuk menghubungkait data 'remote sensing' dengan data sejatantranspirasi di bendang. Nilai ET yang diperhatikan dari 'lysimeter' berada dalam julat 3.2 mm/hari kepada 5.8mm/hari, mana mm/hari kala nilai ET dari pengiraan menggunakan parmeter cuaca berada dalam julat 3.15 kepada 5.72mm/hari. Tiada perubahan signifikan pada musim pertama eksperimen kerana luas kawasan yang kecil dan tiada banyak perubahan keadaan persekitaran di antará blok. Kebanyakan korelasi bagi musim kedua dan ketiga adalah signifikan pada 0.01%. Nilai ET sepadan dari data satelit ialah 4.04 mm/hari kepada 6.54 mm/hari. Dengan menganggapkan ukuran ET dari lysimeter sebagai kaedah yang paling tepat, ET yang ditentukan menggunakan data satelit melebihi anggaran data dari lysimeter sebanyak 10% dan CROPWAT mengurangi anggaran sebanyak 14%.

Penemuan yang signifikan daripada penyelidikan ini ialah nilai ET dapat dianggarkan dalam had yang munasabah bagi kawasan padi di Malaysia dengan menggunakan data Satelit atau perisian CROPWAT. Implikasi daripada penemuan ini ialah banyak masa dan kos dapat dijimatkan dengan menggunakan teknik alternatif ini berbanding kaedah manual menggunakan lysimeter. Ini akan menghasilkan kaedah perancangan pengurusaan air yang lebih cekap. Secara umumnya dengan mengetahui nilai sebenar ET, kalendar tanaman boleh disediakan pada permulaan musim penanaman setelah mengetahui jumlah air yang diperlukan sepanjang musim berkenaan.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my utmost thanks and gratitude to Almighty Allah S.W.T for giving me everything I wish but I have nothing to give Him except thank Him and my salawat to his righteous messenger, prophet Mohamed s.a.w.

My sincere gratitude goes to my first supervisor, Assoc. Prof. Dr. Abdul Rashid Mohamed Shariff for all his critical advice and guidance from inception till completion of my research work. I would also like to thank my second supervisor, Prof. Ir Dr. Mohd Amin Mohd Soom. Without their guidance, the work would not have taken its present shape within the allotted time frame. I feel fortunate to have got this opportunity to work with them. They also worked very hard for me in collecting data from different agencies in the region during our fieldwork. I would also like to thank Dr. Muhamad Radzali Mispan for his support and guidance.

I would like to thank all the paddy field owners for allowing me to use their farms for my field data collection. My appreciations to Mr. Hassan Azhari for his help during the field work. I am also indebted to Ms. Diana in MACRES for her help in my data analysis work. Special thanks to my friends Aimrun Wayayok and Mustafa Yousif for their assistance during the fieldwork. Assistance from colleagues and collaborators at SMART farming lab ITMA and Dept of BAE, Faculty of Engineering, DOA and MACRES is greatly appreciated. It has been a pleasure working with all of them. I, of course, should

not hesitate to express deep appreciation to all my colleagues for their assistance in the research, good wishes and encouragement.

I am grateful for the Government of Sudan for providing me this chance for postgraduate study in Malaysia. Also special thanks for the IRPA project No. 54016 Precision Farming for Rice for financing the research and fieldwork.

I am forever grateful to my beloved parents who taught me the principles of life. My special heartfelt gratitude goes to my brothers and sisters for their warm affection and support. Finally my thanksgiving of my heart goes to my beloved wife Fairouz and my son Ahmed who through their prayers and encouragements kept me going. I really appreciate her for her support and enduring the hardship during my absence.

It is possible for me to achieve this goal of completing my PhD because of them.

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LIST OF ABBREVIATIONS

α	Surface Albedo
γ	Psychrometric Constant
λ	Latent Heat of Vaporization
τ	Day Single-way Transmissivity
Δ	Slope of Saturation Vapor Pressure Curve
AME	Absolute Mean Error
AVHRR	Advanced Very High Resolution Radiometer
CV	Coefficient of Variation
DAS	Days after Seeding
DOA	Department of Agriculture
ERDAS	Earth Resource Data Analysis System
ET	Evapotranspiration
FAO	Food and Agriculture Organization
GIS	Geographical Information System
GPS	Global Positioning System
ha	Hectare
Kc	Crop Coefficient
Ks	Stress coefficient
MACRES	Malaysian Center of Remote Sensing
MARDI	Malaysian Agriculture and Development Institute
NDVI	Normalized Difference Vegetation Index

NIR	Near-Infrared Reflectance
NOAA	National Oceanic Atmospheric Administration
PF	Precision Farming
r	Correlation Coefficient
RH	Relative Humidity
RMSE	Root Mean Square Error
Rn	Net Radiation
RSO	Rectified Skew Orthomorphic
SEBAL	Surface Energy Balance Algorithm for Land
Tmax	Maximum Temperature
Tmin	Minimum Temperature
U	Theil's Inequality Coefficient

CHAPTER 1

INTRODUCTION

1.1 Use of Remote Sensing in Agriculture Water Management

Rice (*Oryza sativa* L.) is the major food crop of nearly half of the world's population. Food security in Asia, where about 60% of the world's population lives, is challenged by increasing food demand and threatened by declining water availability. Of the roughly 530 million ton per year rice produced globally, 90-92% is produced and consumed in Asia, where it provides 35-80% of total calorie uptake in the daily diet of 2.7 billion of Asians (IRRI, 1997). However to keep up with population growth and income-induced for food in most low-income Asian countries (Bouman *et al*, 2000), it is estimated that rice production has to be increased by 56% over the next 30 years (IRRI, 1997).

Water is of finite quantity, thus, a limited resource. As such, it should be managed and used accordingly. There appears to be an increasing competition for water use as the demand for water increases with the growing population (Ines *et al*, 2002). Therefore, a rational approach in water utilization is worth considering. Water use in agriculture has been rated the highest among other water users (Seckler, 1996). In Malaysia large amounts of water is required for irrigation of rice during the dry months, and at the same time it is also required for non agricultural uses such as domestic and industry, (FAO 2003). Hence it could give vital information to the development of improved water use. A promising approach is to determine the potential of water, considering its interrelation

ship with the soil, plant and the atmosphere. Available irrigation water has to be utilized in a manner that matches the water needs of the crop. Water requirements of the crop vary substantially during the growing period mainly due to variation in crop canopy and climatic conditions (Doorenbose and Pruitt, 1977). The knowledge of crop water requirements is an important practical consideration to improve water use efficiency in irrigated agriculture. There is considerable scope for improving water use efficiency by proper irrigation scheduling which is essentially governed by crop evapotranspiration (ETc). Accurate estimation of crop ET is an important factor in efficient water management. In Malaysia, ET for rice varies from 644 mm to 968 mm for main and off-season, respectively (Chan and Cheong, 2001).

Remote sensing has the possibility of offering important water resource-related information to policy makers, managers, consultants, researchers and to the general public (Bastiaanssen *et al*, 2000). This information is potentially useful in legislation, planning, water allocation, performance assessment, impact assessment, research, and in health and environment-related fields. Remote sensing, with varying degrees of accuracy, has been able to provide information on land use, irrigated area, crop type, biomass development, crop yield, crop water requirements, crop evapotranspiration, salinity, water logging and river runoff. This information when presented in the context of management can be extremely valuable for planning and evaluation purposes. Remote sensing has several advantages over field measurements. First, measurements derived from remote sensing are objective; they are not based on opinions. Second, the information is collected in a systematic way, which allows time series and comparison