UNIVERSITI PUTRA MALAYSIA

DRYING PROPERTIES AND RICE PRODUCTION POTENTIAL OF CRACKING SOILS IN THE MUDA IRRIGATION SCHEME

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BY

MD. TARIFUL ISLAM

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“Dedicated to

My Parents ”

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Statement of Originality

Except where specific acknowledgement is given, this research work is reported in this thesis is entirely that of the author.

(Md. Tariful Islam)

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I certify that an Examination Committee has met on 11 December, 1999 to conduct the final examination of Md. Tariful Islam, on his Doctor of Philosophy thesis entitled "Drying Properties and Rice Production Potential of Cracking Soils in the Muda Irrigation Scheme" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommended that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the Degree of Doctor of Philosophy.

DRYING PROPERTIES AND POTENTIAL RICE PRODUCTION OF CRACKING SOILS IN THE MUDA IRRIGATION SCHEME

By

MD. TARIFUL ISLAM

December 1999

Chairman: Professor Dr. Wan Sulaiman Wan Harun

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Three previously puddled rice soils, namely the Chengai, Tebengau, and Tualang series of the Muda Irrigation Scheme were studied both in the field and in the glass house. The objectives of this study were to understand the processes of drying, cracking and re-wetting and relate these to soil properties, to develop a simple model for estimating bypass flow and bypass ratio of cracking soil during land soaking, and to simulate the ORYZA_W model for determining the optimum sowing date, quantifying rice yield, net water use, and crop duration under future climate change scenarios, and assessing the drought effect on irrigated rice yield. Calculated volumetric and linear shrinkage of the Chengai and Tebengau series were similar and greater than those of the Tualang series. The measured shrinkage geometric factor *rs*, with values of around 3, indicated that shrinkage of these three series was isotropic. Comparatively faster moisture depletion and absorption were observed in the Chengai and Tebengau series than in the Tualang series both in the glasshouse and field conditions. Chengai and Tebengau soils showed similar crack width, depth, area, length and volume, these properties being significantly different from those of the Tualang soil. The deepest crack depth below the puddled layer measured by the paint method were 77, 73, and 52 cm in the Chengai, Tebengau, and Tualang series, respectively. A model was developed to quantify bypass flow during land soaking. According to the model, the amount of water that bypassed the topsoil of the three soil series accounted for 59-67% of total input water. Higher yields (10.2 to 10.6 t ha^{-1}) were predicted for the off season (56-98 Day of the Year - DOY) than the main season (9.2 to 9.7 t ha^{-1} during 196-238 DOY). The higher off season yields were associated with higher radiation and longer crop duration. The impact of 15 different climatic scenarios was evaluated. Crop duration (TGP) was shortened by 3 and 2 days during the off and main seasons, respectively, following a 4^0C increase in the daily maximum temperature. Increased CO_2 levels predicted an increase in yield in both seasons. The combinations of increased CO_2 levels and temperatures predicted increased yields for both seasons. The scenarios of three General Circulation Models (GCM) predicted yield reduction in the off season while in the main season, predicted yields were almost similar to current yields. The net water use (NWU) increased with increase in temperature in both seasons for all cases. Increments in CO_2 level did not predict any change for NWU in both seasons. The combinations of increased temperatures and CO_2 levels, and the scenarios of three GCMs predicted an increase of NWU in both seasons. Increased NWU was mainly influenced by temperature increments. Yield differences between crops temporarily stressed at mid-tillering and panicle initiation stages and non-stressed crops were smaller. However, maturity was delayed in both seasons. Large yield reductions were predicted for temporary drought stress at the flowering stage, while maturity was delayed by 3 and 1-day in the off and main seasons, respectively.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia Sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah.

CIRI-CIRI PENGERINGAN DAN POTENSI PENGELUARAN PADI PADA TANAH MEREKAH DI SKIM PENGAIRAN MUDA

Oleh

MD. TARIFUL ISLAM

Disember 1999

Pengerusi: Profesor Dr. Wan Sulaiman Wan Harun

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Tiga siri tanah padi, iaitu, siri Chengai, Tebengau, dan Tualang telah dikaji di ladang dan juga di rumah kaca. Tujuan kajian ini dijalankan adalah untuk: 1) memahami proses pengeringan, rekahan dan pembasahan semula dan menghubungkaitkannya dengan ciri-ciri tanah, 2) menghasilkan satu model ringkas untuk menganggarkan aliran pirau (bypass flow) dan nisbah pirau (bypass ratio) tanah yang merekah semasa pembasahan, dan 3) membuat simulasi model ORYZA.W untuk menentukan masa optimum untuk menyemai, untuk menentukan hasil padi, penggunaan air, dan ketahanan tanaman dibawah cuaca yang sering berubah, dan untuk menilai kesan kemarau keatas padi yang di tanam dengan bantuan pengairan. Kiraan volumetrik dan kecutan lelurus (linear shrinkage) untuk siri Chengai dan Tebengau adalah sama dan lebih tinggi dari siri Tualang. Nilai faktor *rs*, iaitu geometri kecutan (shrinkage geometry) pada tahap 3 menunjukkan pengecutan tanah pada tiga siri tanah tersebut adalah isotropik. Susutan kelembapan dan penyerapan yang lebih cepat dilihat pada siri Chengai dan Tebengau berbanding dengan siri Tualang dalam ujian di rumah kaca dan di ladang. Lebar, kedalaman, panjang dan juga isipadu rekahan pada siri

Chengai dan Tebengau adalah sama dan berbeza jika dibandingkan dengan tanah siri Tualang. Rekahan terdalam di bawah lapisan kedap (puddled) yang dikira dengan menggunakan kaedah cat adalah 77, 73 dan 52 cm pada siri Chengai, Tebengau dan Tualang. Satu model telah dibentuk untuk mengira aliran pirau (bypass flow) semasa pembasahan tanah. Mengikut model ini, jumlah air yang melalui tanah atas pada ketiga-tiga siri tanah tersebut adalah 59-67% dari jumlah keseluruhan air yang diguna. Hasil lebih tinggi (10.2 to 10.6 t ha^{-1}) diramal pada musim pertama (56-98 Day of the Year - DOY) berbanding dengan musim kedua (9.2 to 9.7 t ha^{-1} pada 196-238 DOY). Ini dikaitkan dengan kadar radiasi yang lebih tinggi dan jangka tanaman yang lebih lama pada musim pertama dibanding dengan musim kedua. Kesan bagi 15 senario cuaca yang berbeza telah dinilai. Jangka masa tanaman (TGP) adalah dipendekkan hingga 3 dan 2 hari semasa musim pertama dan musim kedua berikutan peningkatan sebanyak 4^0C pada suhu maksimum harian. Penambahan hasil diramalkan bagi peningkatan paras CO_2 dalam kesemua senario pada kedua-dua musim. Kombinasi paras CO_2 dan suhu yang lebih tinggi diramalkan menambahkan hasil pada kedua musim. Senario dengan tiga model edaran umum (General Circulation Model - GCM) menjangkakan pengurangan hasil pada musim pertama manakala pada musim kedua jangkaan hasil adalah hampir sama dengan hasil semasa. Jumlah penggunaan bersih air (NWU) meningkat dengan peningkatan suhu pada kedua-dua musim dalam semua kes. Penambahan paras CO_2 tidak menunjukkan apa-apa perubahan pada NWU dalam kedua-dua musim. Gabungan peningkatan suhu, paras CO_2 dan senario oleh semua model GCM menunjukkan peningkatan NWU dalam kedua-dua musim. Peningkatan NWU dipengaruhi kenaikan suhu. Perbezaan hasil antara tanaman yang mengalami tegasan kemaran pada pertengahan pembilahan (mid tillering) dan peringkat permulaan panikle dengan yang tidak mengalami tegasan kemaran adalah kecil tetapi kematangan menghadapi dilewatkan pada kedua-dua musim. Pengurangan hasil yang banyak adalah diramalkan bagi keadaan kemarau sementara pada peringkat pembungaan dan kematangan dilewatkan hingga 3 hari pada musim pertama dan 1 hari pada musim kedua.

CHAPTER I

INTRODUCTION

1.1 General Introduction

Rice is grown under diverse climatic, hydrological and edaphic conditions. Based on water regime, four major ecosystems can be distinguished (IRRI, 1989) i.e. i) irrigated, ii) rainfed lowland, iii) upland, and iv) deep water and tidal wetland ecosystems. In lowland ecosystem, water is a major factor as up to 5000 liter of water may be needed to produce 1 kg of rice (Tabal *et al*., 1992). In irrigated ecosystem, the water availability determines the command area of the irrigation project. Similarly, in rainfed lowland system, rainfall largely determines the attainable yield of rice. Efficient management of soil-water, whether its source is irrigation or rainfall, is thus crucial for global rice production.

The Muda Agricultural Development Authority (MADA) Irrigation Scheme or region, also known as the "rice-bowl" of Malaysia, covers a total gross area of 126,000 ha of which 96,000 ha are under paddy cultivation. The scheme produces around 40% of the total production of rice in Malaysia. The parent materials of the soils of the irrigation scheme area are mainly marine sediments deposited during the rise in sea level in the Pleistocene era and riverine sediments (Soo, 1972; Kawaguchi and Kyuma, 1969). The soils are rich in montmorillonitic clay, especially those derived from marine sediments (Furukawa, 1976) and in many parts within the scheme, the soils experience cracking upon drying because of their clayey texture.

In clay soils, decrease in the moisture content is accompanied by the reduction in the soil volume. The soil surfaces shrink due to faster moisture dissipation from the soil mass and shrinkage cracks develop. Puddling of soils during land preparation for irrigated rice destroys the aggregates and accentuates the soil cracking upon drying. Soil cracking turns a clay soil into a varying heterogeneous two-phase medium: soil matrix and cracks. When a clay soil dries, three shrinkage phases appear viz. normal shrinkage, residual shrinkage, and zero shrinkage (Bronswijk, 1988; Ishiguro, 1992). Upon re-wetting, the cracked soils swell because of hydration of the expanding clays and tend to regain their original state. But in practice the cracks are not entirely eliminated without physical manipulation such as puddling. This is because cracks occur not just due to electrochemical forces but also due to rearrangement of particles during water loss and hence cannot be reversed. This process of alternate swelling and shrinkage is quite common and has important consequences for the utilisation of clay soils. In agricultural soils, the main consequence is the rapid transport of water through cracks (bypass flow). Deliberate or unavoidable drying of a previously submerged puddled soil creates soil cracks that may extend through the puddled layer. This may cause a radical change in the seasonal water balance through a tremendous increase in water consumption during land preparation, mainly because of preferential flow down through deep soil cracks (Valera, 1977; IRRI, 1978; Hardjoamidjojo, 1992; Wopereis *et al*., 1994). Part of rain or irrigation water and dissolved fertilisers flow through cracks to the deeper subsoil by-passing the soil profile and may lead to water stress and nutrient deficiency to the crops (Bouma and Dekker, 1978; German *et al*., 1984). The impact of this process to the environment is the leaching of solutes through cracks to the subsoil and tile drains, contributing to pollution of groundwater and surface water (Thomas and Phillips, 1979; Coles and Trudgill, 1985). Cracks are especially prominent in soils containing 2:1 type expanding clay minerals, like montmorillonite and vermiculite. However, they may also be clearly noticeable in kaolinitic soils (Moormann and van Breeman, 1978). Ishiguro (1992) observed crack widths of about 2 cm and crack depths of 7 cm to 20 cm measured in puddled rice soil subjected to 20 to 30 days of drying. However, cracks may reach a depth of 65 cm in dry previously puddled montmorillonitic rice soils (Wopereis *et al*., 1994).

When they are re-wetted with water, the cracks tend to disappear due to swelling and slaking of the soil. The later phenomena decrease the soils' permeability rapidly (Kitamura, 1990). Soil cracking results in not only excessive presaturation water requirement for land preparation but also alter the irrigation and cropping schedules. Onset of drought, occurring commonly once in several years, aggravates the situation of soil cracking and may cause severe loss of rice production in the area due to water shortage. The extent and severity of cracking depends upon some soil physical parameters like the type and amounts of clay, organic matter content and rapidity of moisture depletion from the soil. A mathematical relationship of these parameters with the shrinkage parameters (volumetric shrinkage, shrinkage geometry) would help predict soil cracking and in deciding water management options. Shrinkage characteristics and additional assumptions concerning geometry of swelling and shrinkage, bypass flow, crack volume, and surface subsidence of soils can be calculated.

In cracking soils of the MADA, the width of crack may be 3-12 cm and the depth of crack reaches up to 50-75 cm depth during the dry period (mid January to early April). The geometry of cracks and their effects on bypass flow in the MADA Irrigation Scheme would help better management of the project. The specific problems of the project related to soil water management were: