UNIVERSITI PUTRA MALAYSIA

SAYSTEM APPROACH TO EFFICIENT FIELD MACHINERY UTILIZATION FOR LOWLAND RICE PRODUCTION

SAHR MARVIN BOCKARI-GEVAO.

SYSTEMS APPROACH TO EFFICIENT FIELD MACHINERY UTILIZATION FOR LOWLAND RICE PRODUCTION

By

SAHR MARVIN BOCKARI-GEVAO

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

April 2005

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

SYSTEMS APPROACH TO EFFICIENT FIELD MACHINERY UTILIZATION FOR LOWLAND RICE PRODUCTION

By

SAHR MARVIN BOCKARI-GEVAO

April 2005

Chairman: **Professor Wan Ishak Wan Ismail, PhD**

Faculty: **Engineering**

Within the agricultural sector, there are wide variations in the level and pattern of energy use among various crops. To assess this energy demand, quantitative data on operating conditions is required for each unit operation. With the current increase in world population, energy consumption needs effective planning. One way to optimize energy consumption in agriculture is to determine the efficiency of methods and techniques used.

This study was carried out with the ultimate aim of developing a model that could be used for estimating the energy consumption in a lowland rice production system and to predict the potential yield of rice from operational energy inputs and from quality indices of tillage and planting operations. Tillage systems obtained with factorial combinations of tractor forward speeds obtained from four transmission gear selections and three rotary tilling speeds were compared with respect to effective field capacity and energy requirements for implements used in the typical sequence for each system. The effects of the rotary tillage systems on irrigated soil properties in terms of changes in bulk density, cone index, plasticity index, aggregate uniformity coefficient and organic matter content were also investigated. Energy

analysis for the entire production process included the operational energy consumption by field machinery and human labour, and the indirect energy accounted for by fertilizer, pesticides and seeds used. Functional relationships that allow the quantification of the different processes in the developed simulation model were formulated essentially through the use of secondary data and through curves fitting to some real data. Mathematical equations from agricultural machinery management and empirical equations were employed.

Results from the tillage experiment indicate that differences in field capacity, and fuel and total energy requirements for each tillage system can be attributed primarily to many factors such as soil moisture, soil density, rotary tilling speed, and operation speed and depth. Average total energy inputs in the lowland rice production system (excluding irrigation energy) summed up to about 12225.97 $MJha^{-1}$. As main consumers of energy, fertilizer (7721.03 $MJha^{-1}$; 63.2%) and fuel use (2717.82 $MJha^{-1}$; 22.2%) were identified. Human labour, pesticide, seeds and indirect energy for machinery use had marginal importance, contributing only 0.2%, 0.6%, 6.8% and 6.9%, respectively to the total energy consumption. Focusing on the operational energy consumption for the lowland rice production, the main energy use was in field cultivation activities (2310.24 MJ/ha; 64.2%, planting included) and harvesting (1171.44 $MJha^{-1}$; 32.6%), while spreading of fertilizer and pesticide had only little importance within total mechanization. Indirect energy use for mechanization took about 848.95 $MJha^{-1}$ or 23.6% from total energy use for mechanization of 3595.87 $MJha^{-1}$. Compared to total energy demand of 12225.97 $MJha^{-1}$, indirect energy use for mechanization was even less important (6.9%). Average grain yield was 6470.8 kg ha^{-1}, representing energy output of 108321.75 $MJha^{-1}$, that is, 96095.78 MJ net

energy gain or 8.86 MJ output per MJ input. Energy input per kilogram grain yield was 1.89 $MJkg^{-1}$. The simulation results obtained from the developed computer program regarding direct and indirect operational energy consumption in the lowland rice production were consistent with those obtained from the field study.

The results of the study could serve as a guide to lowland rice farmers in other geographical locations in achieving their production goals. Improvements could be made through the application of the simulation model by figuring out the energy input requirements for all possible combinations of field operations for lowland rice production. It is suggested, as a consequence of this research, that paddy farmers in the Tanjong Karang Rice Irrigation Scheme of Malaysia and other schemes with similar operational conditions adopt the use of Gear 1 High and rotary tilling speed of 175 rpm for tillage operations. The application of this practice should reduce the excessive demand on fossil fuel energy which currently is very expensive and whose continuous availability is unpredictable. This will assist in the on-going campaign to minimize the flux of hard currency out of most developing and transition countries in the form of energy bills. The results and recommendations here are based on the available data on the current practices involved in the lowland rice production system of Malaysia and hence are useful for the current lowland rice crop planning and farm management practices.

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

PENDEKATAN SISTEM KECEKAPAN PENGGUNAAN JENTERA LADANG UNTUK PENGELUARAN PADI TANAH RENDAH

Oleh

SAHR MARVIN BOCKARI-GEVAO

April 2005

Pengerusi: **Profesor Wan Ishak Wan Ismail, PhD**

Fakulti: **Kejuruteraan**

Di sektor pertanian terdapat pelbagai tahap dan bentuk tenaga yang digunakan oleh berbagai-bagai jenis tanaman. Penilaian permintaan tenaga memerlukan data kuantitatif pada keadaan kendalian yang diperlukan oleh setiap unit operasi. Bagi menampung keperluan yang tinggi, keperluan tenaga haruslah diuruskan dengan betul. Salah satu cara untuk mengoptimumkan keperluan tenaga didalam sektor pertanian ialah menggunakan cara-cara yang berkesan dan teknik yang betul.

Tujuan kajian ini adalah membangunkan sebuah model supaya dapat digunakan untuk menganggarkan penggunaan tenaga, dan meramalkan pengeluaran padi daripada sumber operasi tenaga dan juga dari kualiti cucuk tanam serta operasi penanaman. Sistem pembajakan yang didapati daripada gabungan kelajuan traktor hasil daripada pemolihan keempat-empat gear penghantaran dan tiga kelajuan penggembur putar dibuat perbandingan terhadap keberkesanan kecekapan ladang dan juga tenaga yang diperlukan bagi peralatan yang digunakan pada setiap yang dikaji. Perubahan pada sistem pembajakan putaran keatas ciri tanah seperti ketumpatan

organik pada tanah yang turut dikaji. Analisis tenaga pada keseluruhan proses pengeluaran merangkumi operasi penggunaan tenaga oleh jentera ladang dan tenaga buruh, dan juga tenaga tidak langsung seperti baja, racun dan biji benih. Perhubungan Fungsi membenarkan pengkuantitatif pelbagai jenis proses dalam pembangunan model simulasi melalui penggunaan data kajian terdahulu dan juga kesesuaian pencucukan lengkung data sebenar. Persamaan matematik daripada pengurusan jentera pertanian dan persamaan emporikal telah digunakan.

Hasil daripada ujikaji penggemburan mendapati perbezaan pada keupayaan ladang dan keperluan bahanapi dan jumlah tenaga bagi setiap sistem adalah dari faktor-faktor utama termasuklah kelembapan tanah, ketumpatan tanah, kelajuanalat pemutar, kelajuan jentera serta kedalaman. Purata keperluan tenaga didalam sistem pengeluaran padi tanah rendah (tidak termasuk tenaga pengairan) jumlahnya ialah 12225.97 $MJha^{-1}$. Sumber penggunaan tenaga utama seperti baja (7721.03 $MJha^{-1}$; 63.2%), dan kegunaan bahanapi (2717.82 $MJha^{-1}$) telah dikenal pasti. Tenaga buruh. racun serangga, biji benih dan tenaga tidak langsung untuk kegunaan jentera telah menyumbang sebanyak 0.2%, 0.6%, 6.8% dan 6.9% terhadap penggunaan tenaga keseluruhannya. Didalam fokus utama operasi penggunaan tenaga sistem pengeluaran padi tanah rendah, kegunaan utama tenaga ialah pada aktiviti penggemburan tanah (2310.12 $MJha^{-1}$; 64.2% termasuk penanaman) dan penuaian (1171.44 $MJha^{-1}$; 32.6%), sementara penyemburan baja dan racun serangga tidak memberi keutamaan dalam penjenteraan. Kegunaan tenaga tidak langsung untuk penjenteraan ialah 848.95 $MJha^{-1}$ iaitu hanya 23.6% daripada jumlah tenaga yang digunakan pada penjenteraan (3595.87 $MJha^{-1}$), Berbanding dengan jumlah tenaga yang digunakan sebanyak 12225.97 $MJha^{-1}$, kegunaan tenaga tidak langsung pada

penjenteraan adalah jauh lebih rendah iaitu 6.9%. Purata hasil padi ialah 6470.8 $kgha^{-1}$, mewakili keluaran tenaga sebanyak 108321.75 $MJha^{-1}$, dimana, 96095.78 MJ ialah kelebihan tenaga bersih atau 8.86 MJ keluaran setiap MJ kegunaan tenaga. Keperluan tenaga setiap kilogram hasil bijiran ialah 1.89 $MJkg^{-1}$. Keputusan simulasi dari program komputer yang dihasilkan tentang operasi penggunaan tenaga secara langsung dan tidak langsung di dalam pengeluaran padi tanah rendah adalah konsisten dengan hasil kajian di ladang atau sawah padi.

Keputusan yang diperolehi dari kajian ini boleh dijadikan panduan kepada semua pengusaha penanam padi tanah rendah dalam mencapai matlamat yang dikehendaki. Peningkatan pengeluaran hasil padi boleh dicapai melalui model simulasi dengan mengetahui keperluan tenaga bagi setiap pergabungan operasi ladang. Hasil daripada penyelidikan ini adalah dicadangkan, petani Skim Pengairan Padi di Tanjong Karang, Malaysia dan juga skim-skim lain untuk menggunakan kaedah operasi gear 1 tinggi dan kelajuan putaran gembur pada 175psm untuk operasi penggemburan tanah. Penggunaan kaedah ini menggurangkan penggantungan terhadap permintaan tenaga bahanapi. Buat masa ini kos bahanapi adalah tinggi dan bekalan tidak menentu. Ini akan membantu kempen kebangsaan dalam mengurangkan pengaliran wang keluar negara terutama dari segi bil tenaga. Keputusan dan cadangan ini adalah berdasarkan kepada data sediada pada situasi dan amalan semasa yang melibatkan sistem pengeluaran padi tanah rendah di Malaysia dan dengan itu ia berguna untuk pelan pengusahaan penanaman padi dan pengurusan ladang sistematik.

ACKNOWLEDGEMENTS

Writing this acknowledgement is probably one of the most rewarding moments in the preparation of this thesis, because each of the individuals cited here played some significant role during what I view as the 'life cycle' of my study programme at Universiti Putra Malaysia. Even with a careful accounting, there will likely be some who have been inadvertently missed.

I wish to express my warmest, sincerest thanks and deepest gratitude to my advisor, Professor Dr Ir Wan Ishak Wan Ismail who has always been there for me during my stay in Malaysia. He deserves a special gratitude for giving me numerous opportunities and insightful advices, and a boost in my scientific endeavours. The painstaking and judicious advice from the other members of my Thesis Supervisory Committee, Associate Professor Dr Ir Azmi Yahya, Dr Christopher Teh Boon Sung and Dr Chan Chee Wan, is most appreciated and heartily acknowledged. I very much value their time and effort spent in reading the manuscript and making valuable comments and suggestions. I will always cherish their contributions to my professional growth.

My daily association and discussions with Dr Jalloh, Dr Bah and Dr Ousmanu, and Messrs Najim and Aminul have contributed to many ideas that have been formulated and finalized here. Their thoughtfulness and advice have certainly improved the quality of this report.

I owe a large debt of gratitude to the Malaysian Government for its kind financial support provided under the auspices of the Malaysian Technical Cooperation Programme (MTCP) to pursue my studies at Universiti Putra Malaysia. Thanks are also due to the University of Sierra Leone for granting me study leave while pursuing the programme in Malaysia.

Special thanks are due to Tn. Hj. Nasir bin Waris and his staff, particularly Messrs Kamaruddin Sujang and Saiful Baharim, at the Sungai Burong Rice Seed Production Centre of the Department of Agriculture Malaysia, and to Mr Zakaria Ismail of the Department of Biological and Agricultural Engineering UPM for their help during the field experimentation. The assistance of Mr Abd. Aziz Abdullah and other technical staff of the Soil Physics Laboratory in the Faculty of Agriculture UPM is also acknowledged and appreciated.

Last, but certainly not least, sincere thanks go to my wife Melrose for her understanding, continuous support, constant encouragement, patience and sacrifices expressed during the period of my studies in Malaysia, and to my beloved children, Sia, Tamba and Fallah, for being an everlasting source of inspiration.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES