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ENERGY ANALYSIS IN MECHANISED RICE PRODUCTION SYSTEM: SPECIFICALLY FOR CENTRAL THAILAND

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ENERGY ANALYSIS
IN MECHANISED RICE PRODUCTION SYSTEM:
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By

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LIST OF ABBREVIATIONS

Unit

GJ	=	giga joule
h	=	hour
ha	=	hectare
J	=	joule
kcal	=	kilo calorie
kJ	=	kilo joule
kW	=	kilowatt
kW-h	=	kilowatt-hour
L	=	litre
MJ	=	megajoule
man-h	=	man-hour

Variables

AREA	=	operating area, ha
AREWAT	=	total amount of irrigation water required, acre-inch
AVIPTO	=	maximum available PTO power, kW
c	=	adjustment factor to compensate for the effect of day and night weather conditions
CF	=	conversion factors for fuel, MJ/L
ea	=	saturation vapour pressure at mean air temperature, m bar
ed	=	mean actual vapour pressure of the air, m bar
EFC	=	effective field capacity, ha/h
EFPUM	=	pump efficiency, decimal
EFRAIN	=	effective rainfall, inch
EM	=	mechanical efficiency, decimal
ENFU	=	fuel energy input, MJ/ha
ET	=	tractive efficiency, decimal
ET_o	=	reference crop evapotranspiration, mm/day
FDRAF	=	functional draft, N
FEFY	=	field efficiency

FEREN	=	energy input in applying fertiliser, MJ/ha
FGPM	=	flow rate of the pump, gpm
FORATE	=	flow rate of the pump, m^3/h
f(u)	=	wind-related function
HAREN	=	energy input in harvesting
INENGY	=	indirect energy input, MJ/ha
IRE	=	irrigation efficiency
IRREN	=	energy input in irrigation, MJ/ha
LABOUR	=	number of working labourers, men
LANEN	=	energy input in land preparation, MJ/ha
LHA	=	fuel consumption, L/ha
LIFE	=	total useful life of a machine, h
LKWH	=	specific fuel consumption, L/kW-h
MACCF	=	conversion factor for machinery used, MJ/kg
MANHR	=	labour input, man-h/ha
MATCF	=	conversion factor for material used, MJ/kg
MR	=	motion resistance, N
OPRTKW	=	operating power, kW
PLTEN	=	energy input in planting, MJ/ha
PTOREQ	=	equivalent PTO power required, kW
PUMEN	=	energy input in water pumping, kW
RATE	=	application rate of input, kg/ha
REWAT	=	crop evaporation, inch
R_n	=	net radiation in equivalent evaporation, mm/day
SPEED	=	operating speed, km/h
SPREN	=	energy input in spraying pesticide, MJ/ha
TDH	=	total dynamic head, m
TIME	=	operating time, h
TOTEN	=	total energy inputs in rice production, MJ/ha
W	=	temperature-related weighting factor
WEIGH	=	weight of input, kg
WIDTH	=	working width, m

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July 1998

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Rice has long been the most important food and served as a major source of employment in Thailand. Its yearly production is about 20 million metric tons from a total of 10 million hectares. This requires a large amount of energy inputs into the production process.

A rice production system is here defined as any combination of field operations starting from ploughing, raking, levelling, planting, fertilising, spraying, pumping, and ending in harvesting. Each operation requires independent inputs in terms of fuel, indirect energy, and labour. These energy inputs are disbursed to the rice grower in the form of commercial energy and non-commercial energy. An improvement in energy allocation and management for a rice production system will assure the rice grower of a higher return. Understanding the current system of operation and improving one's power of prediction in terms of estimating the energy

required are the best ways to improve a rice production system with regard to energy inputs allocation.

A field study and a simulation study were carried out under this study. The central plain of Thailand was selected for the field survey and 150 rice growers were sampled and interviewed at random. The computer simulation programme was developed based on the classical theory of agricultural machinery management, as well as the empirical equations derived from this study. Fuel requirements, indirect energy requirements, and labour requirements were the main focus of interest. The simulated results yielded results consistent with those obtained from the field survey.

The results of the study indicated that pumping operations required the highest fuel consumption with the values of 1,403.30 and 1,156.28 MJ/ha being obtained from the field study and the simulation study, respectively. The inevitable application of chemical substances in the fertilising stage yielded the maximum indirect energy depletion of 4,318.85 MJ/ha for a rice production system. The highest labour requirement was found for the harvesting operation with a value of 7.93 and 7.85 man-h/ha obtained from the field study and the simulation study, respectively. The results from field study indicated that an overall energy of 11,092.60 MJ/ha together with 29.02 man-h/ha, was required to complete a rice production process. Meanwhile, an overall energy of 10,966.52 MJ/ha together with 29.70 man-h/ha, were the results obtained from the simulation study.

Abstrak disertasi yang dikemukakan kepada Senat, Universiti Putra Malaysia sebagi memehuni keperluan untuk memperolehi Ijazah Doktor Falsafah.

PENGANALISAAN TENAGA TERHADAP SISTEM PENGELUARAN PADI BERJENTERA: KHUSUSNYA UNTUK THAILAND TENGAH

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Sejak sekian lama, padi telah menjadi makanan terpenting dan menyediakan sumber pekerjann yang utama di Thailand. Lebih kurang 20 ribu tan matrik hasil pertanian paripada sejumlah 10 ribu hektar diperolehi setiap tahun. Ini memerlukan gunatenaga yang amat besar terhadap proses pengeluaran.

Sistem pengeluaran padi di sini dihuraikan sebagai gabungan terhadap pekerjaan ladang bermula dari membajak, merata, menanam, membaja, menyembur, mengairi dan akhir sekali menuai. Setiap pekerjaan memerlukan masukan tak bersandar seperti bahan bakar, tenaga tidak langsung dan pekerja. Masukan tenaga ini diagihkan kepada petani dalam bentuk tenaga komersial dan tenaga bukan komersial. Perubahan perlu dilakukan terhadap peruntukan tenaga dan pegurusan sistem pengeluaran bagi memastikan petani memperolehi pulangan yang tinggi. Dengan memahami sistem pengeluaran terkini dan membaiki jangkaan seseorang

dalam menganggar tenaga yang diperlukan adalah cara terbaik memperkenalkan perubahan terhadap sistem pengeluaran padi berbanding peruntukan tenaga.

Penyelidikan tapak dan kajian simulasi telah dijalankan. Bahagian tengah negeri Thailand telah dipilih untuk kajian dan seramai 150 orang petani telah dipilih sebagai contoh dan ditemuramah secara rawak. Program simulasi berkomputer telah dibangunkan berdasarkan teori klasik terhadap pengurusan penjenteraan pertanian dan juga persamaan berdasarkan penyelidikan. Keperluan bahan bakar, tenaga dan pekerja adalah perkara penting yang difokuskan. Keputusan simulasi dan keputusan keuntungan adalah berterusan dengan yang diperolehi daripada kajian tapak.

Keputusan kajian menunjukkan bahawa operasi pengairan memerlukan bahan bakar yang tertinggi untuk melengkapkan tugas dengan nilai 1,403.30 dan 1,156.28 MJ/ha diperolehi daripada penyelidikan tapak dan kajian simulasi. Penggunaan yang tidak dapat dielakkan terhadap kewujudan bahan kimia di peringkat pembajaan menghasilkan pengurangan tenaga maksimum kepada 4,318.85 MJ/ha untuk sistem pengeluaran padi. Keperluan pekerja tertingi didapati daripada operasi penuaian dengan nilai 7.93 dan 7.85 man-h/ha yang didapati daripada penyelidikan tapak dan kajian simulasi. Untuk melengkapkan proses pengeluaran padi di kawasan kajian, keputusan penyelidikan tapak menunjukkan bahawa tenaga keseluruhan 11,092.60 MJ/ha bersama dengan 29.02 man-h/ha, telah diperolehi. Sedangkan tenaga keseluruhan 10,966.52 MJ/ha bersama dengan 29.70 man-h/ha adalah keputusan yang didapati daripada kajian simulasi.

CHAPTER I

INTRODUCTION

Energy Situation

Energy is one of the most valuable resources and a major consideration in the development of any country. In the past, not only was energy not considered a problem but the link between energy and food production had not been revealed. For many years, energy was not an important economic issue because fossil fuels were plentiful and easily extracted at low cost. Due to the low cost, the economy developed and became dependent on energy-intensive use (Grinnell, 1992). The events of the oil embargo in the 1970's focused the attention of the world on both the ultimate finite limit of fossil fuels and the significance of energy for food production. However, more energy is still needed for two reasons: 1) the world population is growing at an exponential rate; and 2) energy use per caput is steadily increasing (Stout, 1979).

Faced with the rising price of fossil fuels and the need to increase food supplies to feed a rapidly growing population, many countries are closely examining the relationship between energy use and agriculture As a consequence, each nation has had to adapt its technologies, institutions and policies to the increasing scarcity of readily available energy. Research has been expanded, national policies have been changed and society has become aware of the probability of a future that will be quite different from our recent past (Christensen et al , 1982)

In Thailand, as in many developing countries, energy resources are extremely limited and incapable of meeting the total demand of all sectors of the economy As the country undergoes a process of modernization, it is becoming critically dependent on petroleum as its major source of energy However, it needs to rely on imported petroleum to meet most of its requirements In 1995, consumption of petroleum products reached 38,005 8 million litres, while the total volume of imports in the form of crude oil and petroleum products increased to 36,978 20 million litres, or 97 3% of the country's overall requirements (Department of Energy Development and Promotion, 1995) The country is forced to spend increasingly large amounts of foreign exchange on imported oil and other energy sources The total bill in 1995 reached more than 4 billion U S dollars (Department of Energy Development and Promotion, 1995) Nevertheless, Thailand still needs more energy to feed its growing population, to ensure that the nation continues to develop, and to raise the overall standard of living

Energy and Agriculture

Agriculture is considered to be a process of energy conversion in that it converts solar energy through the photosynthetic process in agriculture to food energy for humans and feed for animals (Stout, 1989). Defined as the application of science and technology for the purpose of enhancing yields, modern agriculture has undergone increasingly rapid changes in recent decades. For industrialized countries, technology based on mechanical power and other advanced inputs has rendered farming much more capital intensive. This level of agricultural production technology has not been widely adopted in developing countries and, where it has, the results have been variable (FAO, 1985). However, it was stated in the workshop on energy and agriculture that if more food is to be produced in developing countries, more energy-intensive mechanisation is required (Board on Science and Technology for International Development, 1981). Human and animal power may not be sufficient to feed a growing population. The need for timely operations often leaves no choice but to use machines. When the purpose of mechanisation is to increase productivity of the land, the process of choosing the right type of mechanisation is more complicated and requires studies to be conducted to determine the constraining factors and the optimum allocation of resources. Otherwise, problems can accompany mechanisation, such as over investment, fuel shortages, safety hazards, and the relocation or redundancy of labour. A systematic approach to planning mechanisation needs to be developed (Rijk, 1983).

The energy inputs for agricultural production may consist of freely available resources such as solar energy and wind energy; renewable resources such as organic matter, human and animal power; or finite resources such as fossil fuels. Traditional systems of agriculture rely mainly on freely available and renewable energy resources, while modern agricultural systems consume high quantities of fossil fuel - a finite resource. Obviously, during a period of transition from traditional to modern farming techniques commercial energy use increases sharply. Thus, the use of fossil fuels in agricultural production is being closely scrutinized by many countries and organisations (Lewis, 1982).

The growing demand for information regarding the energy requirement in the production process has led to the development of energy analysis, which is used to evaluate systems and processes in terms of their energy interrelationships. In other words, the entire production process must be analyzed in order to gain insight into the system. Improvements can be made by eliminating undesirable results, such as decreased yields, while at the same time ensuring that energy is utilised in an efficient manner.

In many technical applications, the ratio of energy output per unit of energy input is a standard measure of energy efficiency (Ozkan, 1981a; Christensen et al., 1982; Dahiya and Vasudevan, 1986). By calculating energy efficiency, it is easy to compare the amount of energy used in producing various crops. However, it is worth noting that a system with a low level of energy efficiency may be more desirable than

one with a higher level of energy efficiency if the latter requires large quantities of a scarce resource. This is especially true in agricultural processes in which timely operation is needed. For example, although manual labour is not the most dependable way of controlling weeds,
mechanical methods. A scarcity of manual labour, however,
energy efficient method as an alternative (Nalewaja, 1975). To analyze agricultural production from the point of view of energy, therefore, a tool for the formulation of policy and a basis for energy conservation and guidelines for farm management decisions are needed. An understanding both of energy relationships and the energy requirements of agricultural products is necessary.
to combine them into technological alternatives and to induce choices among them at the aggregate level. These choices often concern ways in which to formulate the best energy policy given the energy sources available. A decision to mechanise involves the substitution of mechanical power for human and animal labour. It requires the formulation of a coherent policy in cases when it has macroeconomic implications with regard to overall employment, the balance of payments, the allocation of energy resources and so on.

Thailand is an agriculture-based country in which 58.7% of the nation's population were engaged in the agricultural sector in the year 1996 (FAO, 1997). The total area covers 51.3 million hectares. About 40%, or 21 million hectares is classified as agricultural land. In accordance with the National Economic and Social Development Plan, whose aim since 1970 has been to accelerate agricultural output to serve the needs of the global market. The adoption of modern technologies has been encouraged to assist the country's traditional agricultural system to maximize crop yields. The kind of farming patterns that satisfied local requirements have been in transition, changing gradually to intensive, open systems, utilising large quantities of the energy-rich inputs which are derived from a fossil fuel base. Consequently, during the period of transition from traditional to more energy-oriented agricultural production methods, a significant increase may be observed in the use of commercial energy. The imported energy components have increased considerably due to the introduction of mechanisation as shown in Table 1.1.

This represents a trend towards an increase in the fossil fuel energy equivalent of the machines themselves and an increase in the energy required to run and maintain such a system. In many developing countries, research has been conducted into energy inputs at various stages of different farming systems, such as mostly mechanised, mixed and animal-operated, as reported by Makhijani and Poole (1975),

Table 1. Imported Agricultural Inputs (USD 1,000) in 1991 to 1995

Inputs	1991	1992	1993	1994	1995
Agr. Machines	149,766	140,274	164,723	212,068	244,883
Crude Fertilisers	730	832	1,321	1,360	1,400
Manuf. Fertilisers	404,300	494,730	539,760	537,880	547,500
Pesticides	110,169	129,378	120,553	127,8	127,800
Total	664,965	765,214	826,357	879,133	921,583

Sources: FAO,

Leach (1976), Chancellor (1978), Pathak and Singh (1978), Mohd. Zohadie (1981), Kuether and Duff (1981), Bohle (1991) and Singh and Singh (1992).

As far as energy development for the future is concerned, more efficient energy management is necessary. Although agriculture accounts for only a small fraction of the overall energy consumption, it clearly deserves to be given the highest priority. It is a critical factor in food production and represents a sizable cash expense for the farmers who form the majority of the population, but possess limited purchasing power. In assessing the form this transition is likely to take in the future, it is useful to examine the present use of commercial energy and the current availability of labour for purposes of agricultural production. Energy management requires an adequate energy information base, including information regarding energy consumption patterns and in particular an understanding of energy distribution in agricultural practices. This, in turn, will help to offer a firm foundation for making decisions on energy and for formulating agriculture policy as a whole.

Importance of Rice

In terms of production,

most important food crop in the world if one considers the rice growing area and the number of people depending on the crop. Globally, rice ranks second to wheat in terms of area harvested as shown for 1995-1996 in Table 1.2. However, in terms of