OPTIMIZATION OF ENERGY INPUTS AND GREENHOUSE GAS EMISSIONS OF WETLAND RICE CULTIVATION IN MALAYSIA

SUHA GAAFAR BABEKIR ELSORAGABY

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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

November 2019

DEDICATION

Dedicated to

My Parents,

My Brothers & sister,

My Husband,

My Friends, and to

My Lovely kids:

Lamees,

Mohamed,

Monzer,

Layar,

Lareen

......With Love……

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

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Chairman : Professor Ir. Azmi bin Dato' Yahya, PhD
Faculty : Engineering

Rice is currently being the most cultivated cereal crop and most consumable cereal in Malaysia. The country's annual total consumption of rice from 1981 to 2018 has increased 81.6% due to121.4% increase in the population. In order to meet its demand and reduce the importation, the local production of rice has to increase drastically. Increasing production may involve increasing energy consumption and at the same time results with increasing production cost and increasing environment contaminations that resulted from the inefficiency in productions. Ideally, significant increase in the local rice production could be made possible with increasing crop yield within the available crop planted areas through the optimum used of crop inputs to reduce the involved total production cost. Besides that, the total cost production could also be minimized with proper both in adoption and adaptation of the machines and equipment to perform the involved field operations efficiently and effectively.

Extensive field evaluations were conducted in real field conditions from a total of 62.2 hectares (62 lots) of paddy plots at Sungai Burung, North-West Integrated Agricultural Development Authority Selangor under two rice growing seasons. The duration period for the main rice season lasted from 30rd June to 30rd November 2017 while the off-season lasted from 1st January to 1st June 2018. Analysis on both the crop inputs and outputs of the involved paddy plots were conducted to determine the energy and cost of rice production within the study area. The measured crop inputs were converted into the equivalent energy values and the greenhouse gas emissions (GHG) values using the appropriate conversion coefficients. Besides that, crops input costs for each field operations were calculated based on the prevailing market prices of the machineries, agricultural materials and services. Later, the energy inputs and GHG emissions were

optimized using the multi objective genetic algorithm (MOGA) analysis techniques. In addition, evaluations were also being made on the field performance of the field machineries operating in the field plots and final calculations on the mechanization indexes of the respective field operations in wetland rice production.

From the results, the recorded average crop yield in the main season were 7.3 ± 0.4 ton/ha for the transplanting method and 5.9±0.5 for the broadcast seeding method whereas in the off-season were 7.4± 0.3 ton/ha for the transplanting method and 6.2±0.6 ton/ha for the broadcast seeding method. Where else, the total input energy used and GHG emissions in the main season were 15345.73±375 MJ/ha and 465.56±10.45 kgCO_{2eq}/ha in the transplanting method and 16811.98±1239.2 MJ/ha and 490.50±41.77 kgCO2eq/ha in the broadcast seeding method. While the total input energy used and GHG emissions in the off-season were 17571.9±1548.56 MJ/ha and 512.42±35.50 kgCO_{2eq}/ha for the transplanting method and 19018.32±3601.3 MJ/ha and 527.952±99.08 kgCO_{2eq}/ha in the broadcast seeding methods. The energy input in the off-season was higher than the main season due to the fact that in the offseason the farmers used 24.2% and 26.6% higher quantity of fertilizer in the transplanting and broadcasting fields respectively to achieve higher yield because they wanted to follow rice check. The average overall mechanization index was 0.75, and it varied from a lowest value of 0.19 in fertilizing operation to a highest value of 0.99 in harvesting operation for transplanting method. In broadcast seeding method, the average overall mechanization index was 0.63, and it varied from a lowest value of 0.25 in planting operation to a highest value of 0.99 in harvesting operation. Comparisons the on economic cost of production variables in transplanted method and broadcasted method, revealed that broadcasting method enabled farmers in main and off-seasons to save 16.75% and 14.2% of the total cost but the transplanting method showed 2.8 times mean greater net income than the broadcasting method in the main season and 79.3% in the off-season. The benefit-cost ratios of transplanting and broadcasting methods were found to be 1.3 and 1.1, respectively. The developed multi-objective genetic algorism MOGA Model for maximum yield, minimum energy inputs, and minimum greenhouse gas emissions (GHG) showed the energy inputs by the farmers were over excessed than the actual required energy. The accuracies of the models in predicting rice yield is from 90%% to 99.1% and in predicting GHG emissions is from 86.6% to 91.7%. Despite lower consumption of inputs by MOGA, the crop yield was estimated to be at 9.4 ton/ha in transplanting and 9.2 ton/ha in broadcast seeding methods, which are equal to the region’s maximum crop yield under current cultivation and weather conditions.

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

PENGOPTIMUM INPUT TENAGA DAN PERLEPASAN GAS RUMAH HIJAU OLEH TANAMAN PADi BASAH DI MALAYSIA

Oleh

SUHA GAAFAR BABEKIR ELSORAGABY

November 2019

Pengerusi : Profesor Ir. Azmi bin Dato' Yahya, PhD
Fakulti : Kejuruteraan

Beras merupakan bijirin yang paling banyak dimakan di Malaysia. Walaubagaimanapun, jumlah penggunaan beras tahunan negara meningkat dari tahun 1981 hingga 2018 telah meningkat sebanyak 81.6% disebabkan oleh pertambahan penduduk sebanyak 121.4%. Untuk memenuhi permintaan tersebut disamping mengurangkan kadar import, penghasilan beras tempatan perlu ditingkatkan secara drastik. Meningkatkan penghasilan mungkin akan meningkatkan penggunaan tenaga dan pada masa yang sama mengakibatkan peningkatan kos penghasilan dan pencemaran alam sekitar yang disebabkan oleh kurang kecekapan dalam penghasilan. Sebaiknya, peningkatan ketara untuk penghasilan beras tempatan dalam kawasan penanaman boleh dicapai dengan penggunaan sumber input yang optimum yang boleh mengurangkan kos pengeluaran keseluruhan. Disamping itu, kos pengeluaran keseluruhan boleh dikurangkan dengan penggunaan peralatan atau teknologi mesin yang betul yang boleh melaksanakan operasi lading dengan cekap dan berkesan.

Ujian lapangan yang mendalam telah dijalankan di bawah operasi lapangan sebenar dikawasan penanaman padi seluas 61.64 hektar (62 lot) di Sungai Burong, dibawah seliaan Lembaga Pembangunan Pertanian Bersepadu Barat Laut Selangor (IADA) untuk dua musim penanaman. Tempoh penanaman untuk musim utama dari 30 Jun hingga 30 November 2017, manakala untuk musim kedua pada 1 Januari hingga 1 Jun 2018. Analisis input dan output ladang telah dijalankan untuk menentukan kecekapan tenaga dan kos pengeluaran padi dikawasan tersebut. Input ladang yang diukur telah ditukar menjadi nilai tenaga dan nilai perlepasan gas rumah hijau (GHG) menggunakan pekali penukaran yang sesuai. Manakala kos input pula dinilai berdasarkan kadar pasaran semasa untuk jentera, bahan pertanian dan perkhidmatan. Input tenaga dan pelepasan GHG

dioptimumkan menggunakan teknik analisis algoritma genetik pelbagai objektif (MOGA). Kajian ini juga dijalankan untuk menilai indeks mekanisasi operasi dan menguji prestasi mesin yang digunakan dalam operasi lapangan pengeluaran padi.

Daripada keputusan, purata hasil tanaman yang direkodkan pada musim utama adalah sebanyak 7.3 ± 0.4 tan/ha untuk kaedah tanaman secara mengubah dan 5.9 ± 0.5 tan/ha untuk kaedah tanaman secara tabur terus. Untuk musim kedua pula, purata hasil ialah sebanyak 7.4 ± 0.3 tan/ha untuk kaedah tanaman secara mengubah dan 6.2 ± 0.6 tan/ha untuk kaedah tanaman secara tabur terus. Jumlah tenaga masukan yang digunakan dan pelepasan GHG pada musim utama adalah sebanyak 15345.73 ± 375 MJ/ha dan 465.56 ± 10.45 $kgCO_{2eq}$/ha untuk tanaman secara mengubah dan 16811.98 ± 1239.2 MJ/ha dan 465.56 ± 10.45 $kgCO_{2eq}$/ha untuk tanaman secara tabur terus. Manakala jumlah tenaga masukan yang digunakan dan pelepasan GHG di musim kedua adalah sebanyak 17571.9 ± 1548.56 MJ/ha dan 512.42 ± 35.50 $kgCO_2$ eq/ha untuk kaedah tananam secara mengubah dan 19018.32 ± 3601.3 MJ/ha dan 527.952 ± 99.08 $kgCO_2$ eq/ha untuk kaedah tanaman secara tabur terus. Purata indeks mekanisasi adalah 0.75, dan ia berubah dari nilai terendah 0.19 untuk operasi pembajaan dan kepada nilai tertinggi 0.99 untuk operasi penuaian bagi kaedah penanaman secara mengubah. Manakala untuk kaedah penanaman secara tabur terus, purata indeks mekanisasi adalah 0.63, dan ia berubah dari nilai terendah 0.25 untuk operasi penanaman kepada nilai tertinggi iaitu 0.99 untuk operasi penuaian. Perbandingan kos ekonomi pembolehubah pengeluaran untuk kaedah tanaman secara mengubah dan tanaman secara tabur terus mendedahkan bahawa kaedah tanaman secara tabur terus untuk musin utama dan musim kedua membolehkan petani untuk menjimatkan sehingga 16.75% dan 14.2% daripada jumlah kos tetapi kaedah tanaman secara mengubah menunjukkan 2.8 kali peningkatan kepada pendapatan bersih yang lebih tinggi daripada kaedah tabur terus di musim utama dan 79.3% di musim kedua. Nisbah kos manfaat untuk kaedah penananamn secara mengubah dan tabur terus kaedah pemindahan didapati masing-masing 1.3 dan 1.1. Model algoritma MOGA algoritma genetik multi-objektif yang dibangunkan untuk hasil maksimum, input tenaga minimum, dan pelepasan gas rumah hijau minimum (GHG), menunjukkan lebihan input tenaga yang digunakan oleh petani lebih daripada tenaga yang diperlukan. Ketepatan model dalam meramal kuantiti hasil padi adalah dari 90%% ke 99.1% manakala dalam meramal kuantiti perlepasan GHG adalah dari 86.6% ke 91.7%. Walaupun penggunaan input yang lebih rendah ditunjukkan oleh MOGA, hasil tanaman dianggarkan sebanyak 9.4 tan/ha untuk sistem penanaman secara pindah dan 9.2 tan/ha untuk tanaman secara tabur terus, yang mana ianya bersamaan dengan jumlah maksimum pengeluaran padi di kawasan ini berdasarkan kaedah penanaman dan cuaca.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Azmi bin Dato Yahya, PhD
Professor, Ir
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Muhammad Razif bin Mahadi, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Nazmi bin Mat Nawi, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

____
ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Name and Matric No.: Suha Gaafar Babekir Elsoragaby, (GS22400)

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Signature: ________________________
Name of Chairman of Supervisory Committee: Professor Ir. Dr. Azmi bin Dato' Yahya

Signature: ________________________
Name of Member of Supervisory Committee: Dr. Muhammad Razif bin Mahadi

Signature: ________________________
Name of Member of Supervisory Committee: Dr. Nazmi bin Mat Nawi

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Rice crop is cultivated everywhere through the six world continents whereas all field crop production is practiced except Antarctica continent that covered with ice and there is no crops grown. Almost, half of the world population consume rice as their staple food, it count as the second most important cereal crop in the world after wheat and it comes as second crops production after corn (Figure 1.1). Rice crop has been a part of the several countries cultural identities, it is the first crop among the most important food crops through the world in terms of the volume of production that meets the food needs.

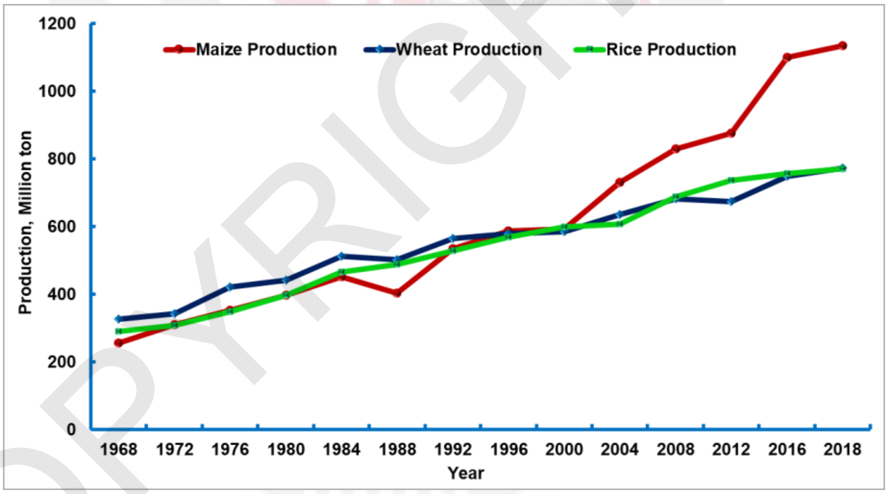

Figure 1.1: World production of wheat, rice and maize from 1967 to 2017 (FAOSTAT 2018)

Arable land in Malaysia for rice cultivation in 2018 was approximately 689,268 hectares according to FAOSTAT (2018) but according to national resources (DOA) rice planted area is 685,548 hectares. The country has ten big rice-growing areas called granary areas that practice crop cultivation twice a year beside other areas classified as non-granary areas. The year-round distribution of rainfall, high humidity, and tropical temperatures serve as major assets supporting the country's rice production. Successive Malaysian governments in the past four decades have affirm that rice production is the national staple food, with the aim of achieving self-sufficiency in production. The focus on self-sufficiency in rice production has led to significant infrastructure developments, such as the establishment of good access roads to rice fields, irrigation/drainage facilities, extension services, machinery packages, special support groups, and incentives, including minimum price guarantee and abundant harvest for farmers.

Rice is the staple food that has received special attention by the Malaysian government. Malaysia self-sufficiency level for rice still remains not much different at 70% for the past five years. The total planted area for rice was around 689,268 ha in 2017 was not enough to produced rice for Malaysian people. Increased production in general can be gained either by expanding the rice cultivated area or achieving the highest field productivity of rice plot by improving the effective use of farming system inputs or by acting both means. Increasing rice production areas in Malaysia is not possible due to limited arable land suitable for rice cultivation in the country, the country's rice harvested area remained relatively constant compared to countries such as Indonesia, which have shown an increasing trend since 1990 (Figure 1.2).

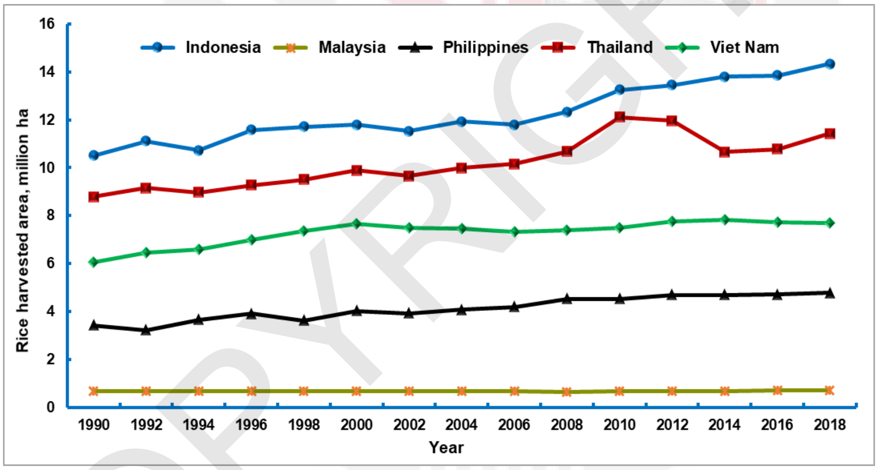

Figure1.2: Total rice harvested area in the Southeast Asia region, 1990 – 2018 (Source: Data from OECD-FAO Agricultural Outlook 2018-2027)

Malaysia is not able to achieve a production boosting in terms of reaching the level of self-sufficiency of rice by 100%, because the increase in rice productivity over the years has not been proportionate with the declination of rice cultivated area, growing of population and changing of people eating habit. In order for the country to be completely self-sufficient in rice production, the rate of productivity must be significantly increased following the same way as neighbors' countries that has the same problems in reducing the area available for rice cultivation, such as China, which achieved rice production increasing by approximately 74.4%.

Norsida (2009) reported that there are about 300,000 rice farmers depend on rice cultivation as their main source of income.Rice farmers are usually housed in ten major granary areas and several small granaries across the peninsular. Poverty is always inherent to the farming community, especially the rice- growing community. Acording to the record of a World Bank study in 1988, Malaysia was classified as an inefficient rice producer (Pio Lopez 2007). Currently, there are more than five million hectares of land being cultivated for palm oil, compared with just one million hectares for food crops, while the oil palm harvested area has increased over the years, rice harvested area remained relatively stagnant (Figure 1.3) shows the land use for several crops in Malaysia (FAOSTAT 2018).

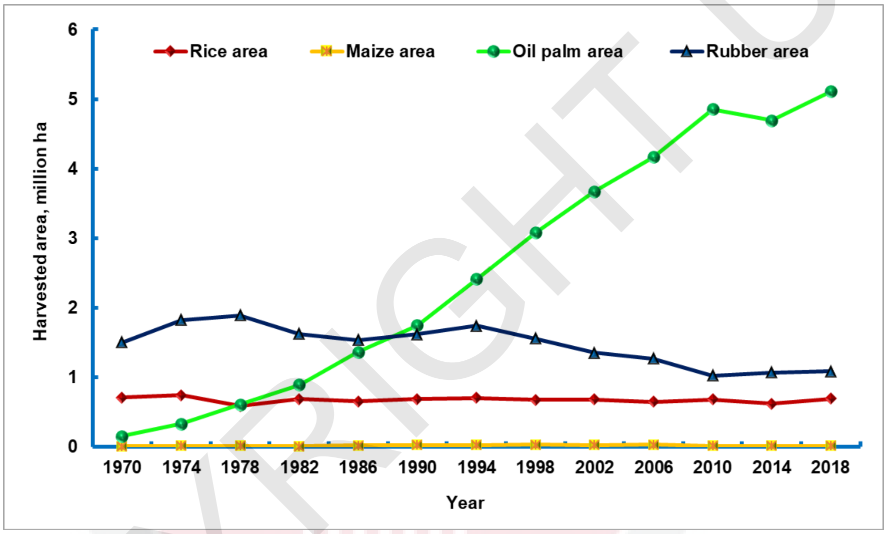

Figure 1.3: Land used for planting oil palm, rubber, rice and corn in Malaysia from 1970 to 2018 (FAOSTAT 2019)

A typical local company cultivates oil palm have thousands hectares of land for oil palm production. On the other hand, food crop farmers, have just about one or two hectares to cultivate. Recently, many farmers have begun to believe that commercial crop plantations are easier to practice than food crops and the prices of palm oil are stable. So, they stop producing food crops and change to oil palm planting. The rice cultivation fields in rice production area like Kedah are being changed to housing and industrial areas. Food crop production needs a lot of labors and farmers have to use a lot of amount of mineral fertilizers and pesticides which is costly, due to high prices of these materials which mostly have to be imported.

Comparing to some neighboring countries, rice production in Malaysia is expensive. In fact, the country lacks a competitive advantage (Murad et al., 2008) in terms of domestic rice production, indicating that rice production is neither viable nor sustainable in the country. Najm et al. (2007) claimed that the cost of imported white ground rice was lower compared to the cost of the same type of locally produced rice. Assuming a total annual output of 2.4 million tonnes and a conservative production cost difference of only RM300/ton between domestic and imported rice for imported rice, this translates into a staggering RM720 million / year in lost revenue for local farmers. It represents a clear case of financial loss that has multiple facets and should not be allowed to pass through. In particular, the poverty rate is higher among rice farmers in the country than in other sectors of the population in other occupations.

The enormous variation in yields, especially at the farm level, is of concern, and therefore its nature needs to be investigated, and it causes firm and effective action. The most viable method is to conduct a comprehensive studies on farm input and output analysis (energy analysis), which cover the processes involved in wet rice cultivation, in the most productive irrigation systems in the country. In this way, the technical competence of the farmers participating in the study will be revealed along with their farming practices. So that the practices of the most efficient farmers, among them, can be models for the less performing farmers to adopt, especially by farmers engaged in less productive irrigation schemes in the country. This becomes necessary because any real improvement in rice productivity can only be achieved through efficiency.

Mechanized farming system need the supply of energy in a suitable timing and appropriate stages of the crop production lifecycle to gain high potential yields. The consumed energy that use in mechanized crop production can be classified as direct energy or indirect energy. The energy that used directly in farming system and crop production is basically the fossil fuels that used to operate agricultural machines to performe fields preparation, seeding and transplanting, applying fertilizer, chemicals and lastly crops harvesting. In addition, all types of farm machinery need oils and lubricants for operation. In contrast to direct energy, agriculture consume indirect energy form such as fertilizer and pesticide.

To evaluate the energy efficiency, productivity energy use is very important factor that indicate if the use of energy is highly efficient or not, but the higher productivity of energy use does not always mean that the energy consumption is more economic or more benefit. Energy analysis and optimization shows the methods and ways to reduce the consumption of energy and how to increase the productivity of the energy (Mohammadi et al., 2010a). The increasing in world population made a need to produce more food to meet this increasing, so that has outcome in more expending of energy and natural resources and that because of the lack knowledge of farmers and little skills to use more efficiently methods of energy expenditure. It is known that more consumption of energy definitely results in environment contamination and problematic public health and put bad impact on environment. Use of energy efficiently in farming system and crop production is consider as the fundamental role and essential requirements of development sustainability; which reduces environmental problems, stop destroying the natural resources, and help in constructing a sustainability in farming system and promote an economical and beneficial agricultural production system. The consumption of energy in farming system and crop production has been studied and analyzed by many researchers (Mohammadi et al., 2011a).

In farming system, analysis of energy is often done to find how and where energy is used, then the analytical data gained is used to increase efficient energy use and reduce expenses. In order to improove the energy expenditure in crop production, a stringent performance assessment methodology must be adopted to evaluate the inefficiency level of the farming system when using energy inputs and propose adequate management system for waste practices and turn the profession to be a beneficial. Using method for modeling operations to evaluate performance is effective.

1.2 Statement of the problem

Efficient energy use, one of the basic requirements for agricultural sustainability. Energy use, it has been increasing due to limited arable land with the growing global population, and desire for higher living standards. Higher energy inputs also increase greenhouse gas emissions (GHG) from the agricultural sector (Nabavi-Pelesaraei et al, 2016a). Dramatic increases in crop yields per hectare have been achieved in the developed countries through the use of improved varieties together with commercial energy inputs particularly mineral fertilizers, farm machinery, pump irrigation and chemical pesticides. For example, with commercial energy use of about 1500 kilogram oil equivalent (kg OE) per hectare for rice and 700 kg OE per ha for maize, yield levels of more than 5 metric tonnes per ha can usually be obtained. This is over 5 times than the yield normally obtained with traditional production methods. Data pertaining to consumption of overall fertilizer NPK in the world during 2002 to 2016 is presented in (Figure 1.4) annual fertilizer of Nitrogen, Phosphate and Potassium consumption increased by 33.51, 40.49 and 45.38%, respectively for the world. While for overall pesticides use increased by 34.76%.

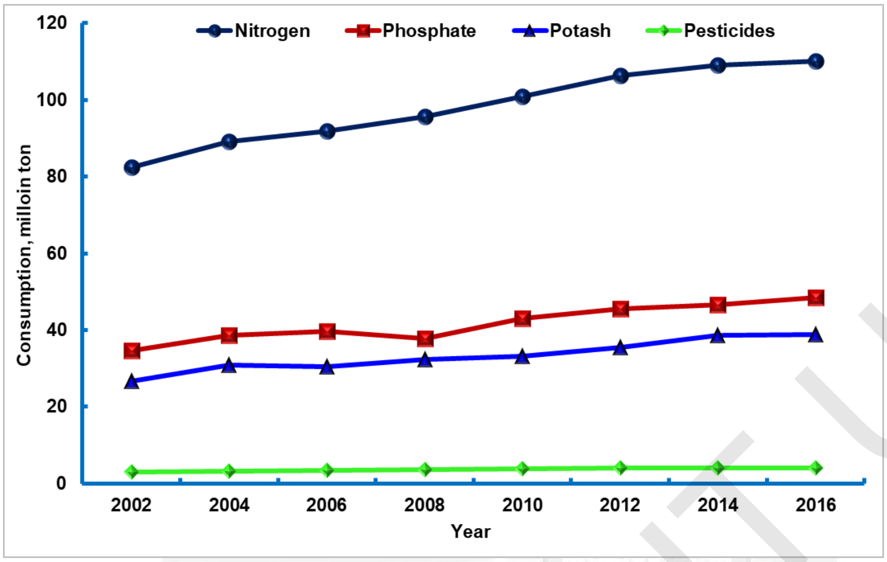

Figure 1.4: World consumption of Nitrogen, Phosphate, Potassium and total pesticides from 2002 to 2016 (FAOSTAT 2018)

Rice production involves several energy expending operations which include seed selection, seed-bed and land preparation, planting, transplanting, seeding, fertilizing, pest management, harvesting, threshing and drying. In general, crop production consume energy directly in machinery and equipment operating, and indirectly as the use of fertilizers and chemicals. The availability of timely adequate energy in sufficient quantities, is necessary for completing rice production in write time, as it is essential to ensure maximum production. In order to maximize the benefits, farmers must have the right energy mix at the right time. High expenditure of the energy input refers to non-economic producing and therefore waste, this may result in reduced or lost benefits, increases global warming and puts some pressure on the environment. Less consumed energy than the required, make it impossible to reach the maximum level of productivity that ensure the required level of food sufficiency.

Many ways could be used for energy optimization that consumed in farming system and crop production, such as determination of the more efficient methods and effective techniques that can be used (Bockari-gevao et al., 2005a). Energy input normally is proportionate directly with the crop yield as the output energy, several studies showed that fertilizers and Fuel often has the highest share of all consumed energy farming system and crop production, and this with a hypothesis assume that optimum energy productivity is gained at a low level of farming mechanization system and mechanization energy sharing is very small, because if mechanization energy increase, will result in increased crop yield with decreasing rate (Bockari-Gevao et al., 2005b).

Various types of machinery are used in modern rice cultivation in Malaysia. These machines operated by combustion of fossil fuels. Information on the amount of fuel use can easily indicate the future cost of fuel that farmers will have to face in the future specially if the price of fuel increase, and encourage them to adopt agricultural practices that will improve fuel consumption more rigorously. In addition to that data from fuel consumption amount by machines in the field operations can be used to develop predictive fuel models for use at the farm level by farmers and also to estimate the level of CO_2 emissions due to fuel use in rice cultivation. Any reduction in fuel use in rice cultivation will effect on reducing CO_2 emissions which would have positive impact on the environment and thus promoting sustainable production and for the government information on fuel consumption.

The lack of sufficient manpower in the rice farming sector is another area of great concern for both farmers and agricultural policy makers because of its strong impact on the cost of production and the need to achieve timely completion of critical agricultural operations in order to avoid unnecessary planting losses. At present, studies have shown that the cost of importing ground white rice is lower compared to the degree of similar locally produced rice. One way to reduce production cost is by automating processes with higher human labor participation in rice production. The need for human labor in agriculture decreases as mechanization increases (Baruah and Bora, 2008). Complete information on the level of inclusion of machines in each process is required for the effective assessment of the agricultural mechanization status of the rice production system. This information has the potential to detect critical processes that require mechanization, so as to enhance rice yields through efficient and timely completion of operations. With the right agricultural machinery with the right energy rates, the availability of water for irrigation and proper planning, the density of rice cultivation can be increased in a year, thus increasing annual production.
Currently, there are not enough documented studies on the extent to which machines are used in typical wet rice paddling systems in Malaysia. Agricultural policymakers can use information on the level of machinery participation at each level of rice cultivation in their tasks of developing a comprehensive agricultural mechanization plan for the country, in line with the country's rapid modernization and industrialization. Developments are increasingly making rice production less attractive to educated young people in part due to hard-working perceived field work and low income widely recognized by rice farmers compared to the profits made by a segment of society engaged in other occupations.

Another area of concern is the use of mineral fertilizers and chemical pesticides. Although rice yields increase with increased fertilizer inputs, excessive use of nitrogen fertilizers contaminates the environment and groundwater and may lead to surface erosion and nitrogen leakage. Given the fact that about two-thirds of the requirements of fertilizer that consumed annually in Malaysia are brought by importing them, a change significantly in the fertilizers price on the world market definitely will affect the level and policy of government subsidies on fertilizers to the rice farmers. For sustainability of rice production, rice farmers must gain a profit and should continue to gain more profit for them for guarantee staying in their occupation in rice field with or without government subsidies. Consolidation and profit can only be achieved if deficiencies practices in the farming system and crop production are removed, that is, the need for optimal use of resources. Optimal use of fertilizers is very important for guaranteed sustainability in production of rice with low expenses. With the study of farming system energy, the fertilizer amount that needed to maximize yield can be verified through developing optimization model.

Several studies showed the significant effect and contribution of use the chemical pesticides for improving rice yield but also it is very clear that use of pesticides excessively regardless of environmental pollution put some negative impacts on cultivated rice crop that is the effect of plant growth and maturity. It is important to mention that the use of insecticides less than the dose recommended by manufacture in the product label might cause the pests and insects to mutate and become has a resistant to the chemicals pesticides which will lead to the need of increase application amount and frequencies One of the keys to good pesticide management is following recommendations of manufacturers in their label that includes the dosage per hectare and chemical to the solvent mixing ratio as well as the use of appropriate machines and technology in application performance One way to raise farmers' awareness of the good methods in the use of chemicals spraying is to obtain a computational algorithm that can calculate the optimum required volume of application solution taking into account the recommended dose and mixing ratio of application of the chemicals pesticides.

1.3 Research Objectives

The aim of the study is to summarize the energy use patterns and analyze the energy input–output of the wetland rice cultivation in Malaysia in different planting method, transplanting and broadcast seeding methods, and indicate where savings in the cost of energy used could be made for the rice production to be economical viable and environmentally save.

The specific objectives:

1. To investigate and compare the energy use, GHG emissions, and production cost for transplanting and broadcast seeding wetland rice cultivation in Malaysia.

2. To evaluate the performance of the field machines and mechanization index for the operations in transplanting and broadcast seeding wetland rice cultivation in Malaysia.
3. To develop a regression model for predicting maximum rice yield for given levels of energy inputs.
4. To optimize the energy use and greenhouse gas emissions (GHG) of transplanting and broadcast seeding wetland rice cultivation in Malaysia by using multi-Objective genetic algorithm (MOGA) method.

1.4 Scope of the Study

Rice in Malaysia is cultivated in lowland (wetland) and upland (dryland), this study is limited to lowland rice fields. Farmers in Malaysia cultivate rice using both transplanting and direct seeding cultivation, this study is included both systems transplanting and direct seeding. Both broadcasting and transplanting systems are performed on a puddled soil. Farmers practicing six operations during every season namely slashing, chemicals spraying, tillage, planting (broadcasting or transplanting), irrigation, fertilizing, and harvesting. The research is however, limited to evaluating all operations mentioned above that were practiced by farmers in the study area except irrigation operation. For transplanting rice, this study not included the nursery stage because the farmers do not plant seedlings in their farm, they just buy it from producers.

In general, the study scope is to develop an optimization model, to analyze and evaluate the input and output of consumed and produced energy and expended cost in wetland rice field cultivation in the intended area, and determine the amount of energy wasteful uses, and calculate cost expenditures connected to that use, and describe all that precisely accordingly to the cultural practices in the rice field. The study, will show a complete computing platform including the various measures indicators of energy and cost, and generate a comprehensive reports on utilization of machinery, all that will be achieved by analyzing the farm collected data.

1.5 Thesis Layout

The thesis comprises five chapters which are summarised as follows:

Chapter One provides a general background of the research topic, identifies the statement of the problem, and objectives of the study. The scope and limitations of the study are also explained.

Chapter Two presents the literature review of rice production, the differences between transplanting and broadcast seeding, analaysis of energy in crops production, and greenhouse gases emissions scenario.

Also, it contains an investigation of optimization techniques in crops production and made a comparison between data envelopment analysis (DEA) and multi objective genetic algorithm (MOGA) production and chose the best technique.

Chapter Three covers the description of the study area, the methodology of collecting data for wheather, field performance, time motion, energy analysis, and GhG analysis. The methodology of applying optimization of MOGA and the comparison between conventional versus Garmin measured human energy are peresnt in this chapter.

Chapter Four presents, explains and discusses field performance and time motion, analysis of energy and greenhouse gas emissions, production cost, mechanization index, and optimization of energy and GHG emissions results, and the outcomes of the data analysis after made the comparison between transplanting and broadcast seeding wetland rice cultivation in Malaysia.

Chapter Five presents the general conclusion derived from this work and proceeds to recommendations for future work. Also, the novelty of the study and contributions to knowledge are presents in this chapter.

REFERENCES

Abbas, A., Yang, M., Yousaf, K., Ahmad, M., Elahi, E., & Iqbal, T. (2018). Improving Energy Use Efficiency of Corn Production by Using Data Envelopment Analaysis (A Non-Parametric Approach). Fresenius Environmental Bulletin, 27(7), 4725-4733

Afshar, R. K., Alipour, A., Hashemi, M., Jovini, M. A., & Pimentel, D. (2013). Energy inputs-yield relationship and sensitivity analysis of pistachio (Pistacia vera L.) production in Markazi Region of Iran. Spanish Journal of Agricultural Research, 11(3), 661–669.

Afza, K. N., Mohamad, O., and Alias, I. (2017). Variation of panicle characteristics in seven rice genotypes and F 2 populations. Journal of Tropical Agriculture and Food Science, 45(1), 89–99.

AghaAlikhani, M., Kazemi-Poshtmasari, H., & Habibzadeh, F. (2013). Energy use pattern in rice production: A case study from Mazandaran province, Iran. Energy Conversion and Management, (69), 157–162.

Aguilera, E., Guzmán, G. I., Infante-Amate, J., Soto, D., García-Ruiz, R., Cid, A., ... & González de Molina, M. (2015). Embodied energy in agricultural inputs. Incorporating a historical perspective. Sociedad Española de Historia Agraria. DT-SEHA 1507.

Akcaoz, H. (2011a). Analysis of energy use for banana production: A case study from Turkey. African Journal of Agricultural Research, 6(25), 5618–5624.

Akcaoz, H. (2011b). Analysis of energy use for banana production: A case study from Turkey. African Journal of Agricultural Research, 6(25), 5618–5624.

Akpinar, M. G., Ozkan, B., Say\.In, C., Fert, C., & others. (2009). An input-output energy analysis on main and double cropping sesame production. Journal of Food, Agriculture & Environment, 7(3/4), 464–467.

Alizadeh, H. H. , & Taromi, K. A. M. (2014). An investigation of energy use efficiency and CO2 emissions for grape production in Zanjan Province of Iran. International Journal of Advanced Biological and Biomedical Research, 2(7), 2249-2258.

Alizadeh, M. R., & Allameh, A. (2013). Evaluating rice losses in various harvesting practices. Int. Res. J. Appl. Basic Sci, 4, 894-901.

Amponsah, S. K., Addo, A., Dzisi, K. A., Moreira, J., & Ndindeng, S. A. (2017a). Performance Evaluation and Field Characterization of the

Sifang Mini Rice Combine Harvester. Applied Engineering in Agriculture, 33(4), 479–489. doi:10.13031/aea.11876.

Amponsah, S. K., Addo, A., Dzisi, K., Moreira, J., & Ndindeng, S. A. (2017b). Comparative evaluation of mechanised and manual threshing options for Amankwatia and AGRA rice varieties in Ghana. Journal of Agricultural Engineering, 48. doi:10.4081/jae.2017.684.

ASABE Standards. (2011). D497.7: Agricultural machinery management data. St. Joseph, MI: ASABE.

ASAE Standards. (2005). S495.1: Uniform terminology for agricultural machinery management. St. Joseph, MI: ASAE.

ASAE Standards. ASAE D497.4 Agricultural Machinery Management Data. Science, 85(2210), 350–357. https://doi.org/10.1126/science.85.2210.446-a

Asgharipour, M. R., Mondani, F., & Riahinia, S. (2012). Energy use efficiency and economic analysis of sugar beet production system in Iran: A case study in Khorasan Razavi province. Energy, 44(1), 1078–1084. https://doi.org/10.1016/j.energy.2012.04.023

Azman, E. A., Jusop, S., Ishak, C. F., & Ismail, R. (2014). Increasing rice production using different lime sources on an acid sulfate soil in Merbok, Malaysia. Pertanika Journal of Tropical Agricultural Science, 37(2), 223–247.

Banaeian, N., Omid, M., & Ahmadi, H. (2011). Energy and economic analysis of greenhouse strawberry production in Tehran province of Iran. Energy Conversion and Management, 52(2), 1020–1025.

Banaeian, N., & Zangeneh, M. (2011). Study on energy efficiency in corn production of Iran. Energy, 36(8), 5394–5402. doi:10.1016/j.energy.2011.06.052

Baloch, A. W., Soomro, A. M., Javed, M., Ahmed, M., Bughio, H. R., Bughio, M. S., and Mastoi, .N. N. (2002). Optimum plant density for high yield in rice (Oryza sativa L.). Asian Journal of Plant Sciences, 1(1), 25–27. https://doi.org/10.3923/ajps.2002.25.27

Baran, M. F., Gökdogan, O., & Ouguz, H.. I. (2017). Determining the energy usage efficiency of walnut (Juglans Regia L.) cultivation in Turkey. Erwerbs-Obstbau, 59(1), 77–82.

Baran, M. F., & Gokdogan, O. (2016). Determination of energy balance of sugar beet production in Turkey: a case study of Kırklareli Province. Energy Efficiency, 9(2), 487-494.

Baruah, D. C., & Bora, G. C. (2008). Energy demand forecast for mechanized agriculture in rural India. Energy Policy, 36(7), 2628–2636. doi:10.1016/j.enpol.2008.03.030

Barut, Z. B., Ertekin, C., & Karaagac, H. A. (2011). Tillage effects on energy use for corn silage in Mediterranean Coastal of Turkey. Energy, 36(9), 5466–5475. doi:10.1016/j.energy.2011.07.035

Bhowmik, S., Sarkar, M., and Zaman, F. (2013). Effect of spacing and number of seedlings per hill on the performance of aus rice cv. NERICA 1 under dry direct seeded rice (DDSR) system of cultivation. Journal of the Bangladesh Agricultural University, 10(2), 191–196. doi:10.3329/jbau.v10i2.14681

Bilalis, D., Kamariari, P.-E., Karkanis, A., Efthimiadou, A., Zorpas, A., & Kakabouki, I. (2013). Energy inputs, output and productivity in organic and conventional maize and tomato production, under mediterranean conditions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 41(1), 190–194.

Birhane, A. (2013). Effect of planting methods on yield and yield components of Rice (Oryza sativa L.) varieties in Tahtay Koraro Wereda, Northern Ethiopia. Int. J. Technol. Enhance. Emerg. Eng. Res, 1(5), 1–5.

Bockari-Gevao, S. M., bin Wan Ismail, W. I., Yahya, A., & Wan, C. C. (2005). Analysis of energy consumption in lowland rice-based cropping system of Malaysia. Energy, 27(4), 820.

Bockari-Gevao, S.M., 2005. Systems approach to efficient field machinery utilization for lowland rice production. Unpublished PhD thesis, Universiti Putra Malaysia.

Canakci, M., & Akinci, I. (2006). Energy use pattern analyses of greenhouse vegetable production. Energy, 31(8-9), 1243–1256. https://doi:10.1016/j.energy.2005.05.021

Canakci, M., Topakci, M., Akinci, I., & Ozmerzi, A. (2005). Energy use pattern of some field crops and vegetable production: Case study for Antalya Region, Turkey. Energy Conversion and Management, 46(4), 655–666. doi:10.1016/j.enconman.2004.04.008

Çetin, B., & Vardar, A. (2008). An economic analysis of energy requirements and input costs for tomato production in Turkey. Renewable Energy, 33(3), 428–433. . doi:10.1016/j.renene.2007.03.008

Chaichana T, Phethuayluk S, Tepnual T, Yaibok T. Energy consumption analysis for SANGYOD rice production. Energy Proc 2014;52:126e30. https:// doi.org/10.1016/j.egypro.2014.07.062.

Chauhan, N. S., Mohapatra, P. K. J., & Pandey, K. P. (2006). Improving energy productivity in paddy production through benchmarking—An application of data envelopment analysis. Energy Conversion and Management, 47(9-10), 1063–1085. . doi:10.1016/j.enconman.2005.07.004

Chamsing, A., Salokhe, V. M., & Singh, G. (2006). Energy Consumption Analysis for Selected Crops in Different Regions of Thailand. In 2004) Agricultural Engineering International: the CIGAR Ejournal. Manuscript EE 06 013.

Chaudhary, V. P., Gangwar, B., & Pandey, D. K. (2006). Auditing of energy use and output of different cropping systems in India. Agricultural Engineering International: CIGR Journal.

Chaudhary, V. P., Gangwar, B., Pandey, D. K., & Gangwar, K. S. (2009). Energy auditing of diversified rice--wheat cropping systems in Indo-gangetic plains. Energy, 34(9), 1091–1096.

Chaudhary, V. P., Singh, K. K., Pratibha, G., Bhattacharyya, R., Shamim, M., Srinivas, I., & Patel, A. (2017). Energy conservation and greenhouse gas mitigation under different production systems in rice cultivation. Energy, 130, 307–317. doi:10.1016/j.energy.2017.04.131

Chauhan, B. S., and Johnson, D. E. (2010). Implications of narrow crop row spacing and delayed Echinochloa colona and Echinochloa crus-galli emergence for weed growth and crop yield loss in aerobic rice. Field Crops Research, 117(2-3), 177–182. doi:10.1016/j.fcr.2010.02.014

Chauhan, B. S., and Johnson, D. E. (2011). Row spacing and weed control timing affect yield of aerobic rice. Field Crops Research, 121(2), 226–231. doi:10.1016/j.fcr.2010.12.008.

Chauhan, N. S., Mohapatra, P. K. J., & Pandey, K. P. (2006). Improving energy productivity in rice production through benchmarking—an application of data envelopment analysis. Energy Conversion and Management, 47(9–10), 1063–1085.

Cicek, A., Altintas, G., & Erdal, G. (2011). Energy consumption patterns and economic analysis of irrigated wheat and rainfed wheat production: case study for Tokat region, Turkey. Bulgarian Journal of Agricultural Science, 17(3), 378-38

Data from OECD-FAO Agricultural Outlook 2018-2027 (Accessed on 20 Aug 2019)

Davoodi, M. J. S., Houshyar, E., & others. (2009). Energy consumption of canola and sunflower production in Iran. American-Eurasian Journal of Agricultural and Environmental Science, 6(4), 381–384.

De Datta, S. K. (1981). Principles and Practices of Rice production. Int. Rice Res. Inst.

Demircan, V., Ekinci, K., Keener, H. M., Akbolat, D., & Ekinci, C. (2006). Energy and economic analysis of sweet cherry production in Turkey: a case study from Isparta province. Energy Conversion and Management, 47(13–14), 1761–1769.

Denman, K.L., Brasseur, G., Chidthaisong, A., Ciais, P., Cox, P.M., Dickinson, R.E., Hauglustaine, D., Heinze, C., Holland, E., Jacob, D., Lohmann, U., Ramachandran, S., da Silva Dias, P.L., Wofsy, S.C., Zhang, X., 2007. Couplings between changes in the climate system and biogeochemistry. In: Solomon, S., Qin, D., Manning, M. (Eds.), Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (Eds.), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, ambridge, United Kingdom and New York, NY, USA

Department of Agriculture Peninsular Malaysia (DOA) 2019. Paddy statistics of Malaysia 2017

Dilipkumar, M., BURGOS, N. R., CHUAH, T. S., & ISMAIL, S. (2018). Cross-Resistance to Imazapic and Imazapyr in a Weedy Rice (Oryza sativa) Biotype Found in Malaysia. Planta Daninha, 36(0). doi:10.1590/s0100-83582018360100005

Elhami, B., Akram, A., & Khanali, M. (2016). Optimization of energy consumption and environmental impacts of chickpea production using data envelopment analysis (DEA) and multi objective genetic algorithm (MOGA) approaches. Information Processing in Agriculture, 3(3), 190–205. doi:10.1016/j.inpa.2016.07.002

Elsoragaby, S., Yahya, A., Mahadi, M. R., Nawi, N. M., & Mairghany, M. (2019a). Energy utilization in major crop cultivation. Energy, 173, 1285–1303. doi:10.1016/j.energy.2019.01.142

Erdal, G., Esengün, K., Erdal, H., & Gündüz, O. (2007). Energy use and economical analysis of sugar beet production in Tokat province of Turkey. Energy, 32(1), 35–41.

Erdal, H., Esengun, K., & Erdal, G. (2009). The functional relationship between energy inputs and fruit yield: a case study of stake tomato in Turkey. Journal of Sustainable Agriculture, 33(8), 835–847.

Esengun, K., Erdal, G., Gündüz, O., & Erdal, H. (2007). An economic analysis and energy use in stake-tomato production in Tokat province of Turkey. Renewable Energy, 32(11), 1873–1881.

Esengun, K., Gündüz, O., & Erdal, G. (2007). Input--output energy analysis in dry apricot production of Turkey. Energy Conversion and Management, 48(2), 592–598.

Eyitayo, O. A., Chris, O., Ejiola, M. T., & Enitan, F. T. (2011). Technical efficiency of cocoa farms in Cross River State, Nigeria. African Journal of Agricultural Research, 6(22), 5080-5086.

Fadavi, R., Keyhani, A., & Mohtasebi, S. S. (2012). Estimation of a Mechanization Index and Its Impact on Energy and Economic Factors in Apple Orchard in Iran. Asian Journal of Agriculture and Rural Development, 2(2), 248.

Fadavi, R., Keyhani, A., & Mohtasebi, S. S. (2010). Estimation of a Mechanization Index in Apple Orchard in Iran. Journal of Agricultural Science, 2(4). doi:10.5539/jas.v2n4p180

FAOSTAT, F. (2018). Agriculture Organization Corporate Statistical Database. Accessed on, 12-06. http://www.faostat.fao.org/

Flores, E. D., Cruz, R. S. M. Dela, & Antolin, M. C. R. (2016). Energy use and greenhouse gas emissions of farmer-level sweet potato production systems in the Philippines. Asian Journal of Applied Sciences (ISSN: 2321--0893), 4(01).

Gezer, I., Acaroğlu, M., & Haciseferoğullari, H. (2003). Use of energy and labour in apricot agriculture in Turkey. Biomass and Bioenergy, 24(3), 215–219.

Ghatrehsamani, S., Ebrahimi, R., Kazi, S. N., Badry, A. B., & Sadeghinezhad, E. (2016). Optimization model of peach production relevant to input energies--Yield function in Chaharmahal va Bakhtiari province, Iran. Energy, 99, 315–321.

Ghorbani, R., Mondani, F., Amirmoradi, S., Feizi, H., Khorramdel, S., Teimouri, M., Aghel, H. (2011). A case study of energy use and economical analysis of irrigated and dryland wheat production systems. Applied Energy, 88(1), 283–288.

Goel, A. K., Behera, D., & Swain, S. (2008). Effect of sedimentation period on performance of rice transplanter. Agricultural Engineering International: The CIGR Ejournal, 10, 13pp.

Gokdogan, O., & SEVIM, B. (2016). Determination of Energy Balance of Wheat Production in Turkey: A Case Study of Eskil District of Aksaray Province. Journal of Tekirdag Agricultural Faculty, 13(4).

Gokdogan, O., Erdogan, O., Eralp, O. and Zeybek, A., (2016). Energy efficiency analysis of cotton production in Turkey: a case study from Aydin province. Fresenius Environmental Bulletin, 25(11), 4959–4964.

Gündoğmuş, E. (2006). Energy use on organic farming: A comparative analysis on organic versus conventional apricot production on small holdings in Turkey. Energy conversion and management, 47(18-19), 3351-3359.

Gurunathan, S., & Palanisami, K. (2008). Energy Use and its Efficiency in Tamil Nadu Agriculture: A Case Study of Different Groundwater Development Regions in Coimbatore District of Tamil Nadu. Agricultural Economics Research Review, 21(1).

Gunvantbhai, P. P., Bhut, A. C., & Pankaj, G. (2014). Energy requirement for kharif maize cultivation in Panchmahal district of Gujarat. Journal of AgriSearch, 1(3), 168–172.

Isaac Bamgboye, A., & S. Kosemani, B. (2015). Energy Input in the Production of Cassava. Energy and Environment Research, 5(1). doi:10.5539/eer.v5n1p42

Hai-xin, Z., Xiao-xue, W., Zhen-hua, G., Xiao-qun, H., & Hua-long, L. (2012). Effects of Row-Spacing on Canopy Structure and Yield in Different Plant Type Rice Cultivars. Journal of Northeast Agricultural University (English Edition), 19(4), 11–19. doi:10.1016/s1006-8104(13)60045-8

Hamedani, S. R., Keyhani, A., & Alimardani, R. (2011). Energy use patterns and econometric models of grape production in Hamadan province of Iran. Energy, 36(11), 6345–6351.

Hamedani, S. R., Shabani, Z., & Rafiee, S. (2011). Energy inputs and crop yield relationship in potato production in Hamadan province of Iran. Energy, 36(5), 2367–2371.

Hamzei, J., & Seyyedi, M. (2016). Energy use and input--output costs for sunflower production in sole and intercropping with soybean under different tillage systems. Soil and Tillage Research, 157, 73–82.

Hasanuzzaman, M., Nahar, K., Roy, T. S., Rahman, M. L., Hossain, M. Z., and Ahmed, J. U. (2009). Tiller dynamics and dry matter production of transplanted rice as affected by plant spacing and number of seedling per hill. Academic Journal of Plant Sciences, 2(3), 162-168.

Hassan A. (2011). Assessment of direct seeded and transplanting methods of rice cultivars in the northern part of Iran. African Journal of Agricultural Research, 6(31). doi:10.5897/ajar11.973

Hatirli, S. A., Ozkan, B., & Fert, C. (2005). An econometric analysis of energy input--output in Turkish agriculture. Renewable and Sustainable Energy Reviews, 9(6), 608–623.

Hatirli, S. A., Ozkan, B., & Fert, C. (2006). Energy inputs and crop yield relationship in greenhouse tomato production. Renewable Energy, 31(4), 427–438.

Hematian, A., Bakhtiari, A. A., Yaghubi, O., & Zarei-Shahamat, E. (2013). Optimization of energy consumption in sugar-beet production using genetic algorithm" A case study in Kermanshah Province, Iran". International journal of Agronomy and Plant Production, 4(6), 1351-1356.

Herman, T., Murchie, E. H., and Warsi, A. A. (2015). Rice production and climate change: a case study of Malaysian rice. Pertanika Journal of Tropical Agricultural Science, 38(3), 321-328.

Hirel, B., Le Gouis, J., Ney, B., & Gallais, A. (2007). The challenge of improving nitrogen use efficiency in crop plants: towards a more central role for genetic variability and quantitative genetics within integrated approaches. Journal of Experimental Botany, 58(9), 2369–2387.

Ho, N. K., and Romli, Z. (2002). Impact of direct seeding on rice cultivation: lessons from the Muda area of Malaysia. Direct Seeding: Research Strategies and Opportunities, 398.

Hossain, M., Hoque, M., Wohab, M., Miah, M. M., & Hassan, M. (2015). Technical and economic performance of combined harvester in farmers field. Bangladesh Journal of Agricultural Research, 40(2), 291–304. doi:10.3329/bjar.v40i2.24569

Hosseinzadeh-Bandbafha, H., Nabavi-Pelesaraei, A., Khanali, M., Ghahderijani, M., & Chau, K. (2018). Application of data envelopment analysis approach for optimization of energy use and reduction of greenhouse gas emission in peanut production of Iran. Journal of Cleaner Production, 172, 1327–1335. doi:10.1016/j.jclepro.2017.10.282

Hosseinzadeh-Bandbafha, H., Safarzadeh, D., Ahmadi, E., Nabavi-Pelesaraei, A., & Hosseinzadeh-Bandbafha, E. (2017). Applying data envelopment analysis to evaluation of energy efficiency and decreasing of greenhouse gas emissions of fattening farms. Energy, 120, 652–662. doi:10.1016/j.energy.2016.11.117.

Houshyar, E., Dalgaard, T., Tarazkar, M. H., & Jørgensen, U. (2015). Energy input for tomato production what economy says, and what is good for the environment. Journal of Cleaner Production, (89), 99–109.

Huang, M., Zou, Y., Jiang, P., Xia, B., Feng, Y., Cheng, Z., and Mo, Y. (2011). Yield Component Differences between Direct-Seeded and Transplanted Super Hybrid Rice. Plant Production Science, 14(4), 331–338. doi:10.1626/pps.14.331

Islam, M. S., Akhter, M. M., Rahman, M. S., Banu, M. B., and Khalequzzaman, K. M. (2008). Effect of nitrogen and number of seedlings per hill on the yield and yield components of T. aman rice (BRRI dhan33). International Journal of Sustainable crop production, 3(3), 61-65.

Jekayinfa, S. O., Afolayan, S. O., Olaniyan, A. A., & Atobatele, O. (2014). Tropentag 2014, Prague, Czech Republic September 17-19, 2014. In Conference on International Research on Food Security.

Khan, M. A., Khan, S., and Mushtaq, S. (2009). Energy and economic efficiency analysis of rice and cotton production in China. Sarhad journal of agriculture, 25(2), 291-300.

Kamaruddin, R., & Ali, J. (2013). Happiness and its Influencing Factors among Rice Farmers in Granary Area of MADA, 399–407.

Karimi, M., Beheshti Tabar, I., & Khubbakht, G. M. (2008). Energy production in Iran's agronomy. Am. Eurasian J. Agric. Environ. Sci, 4(2), 172-177.

Karimi, M., RajabiPour, A., Tabatabaeefar, A., & Borghei, A. (2008). Energy analysis of sugarcane production in plant farms a case study in Debel Khazai Agro-industry in Iran. American-Eurasian Journal of Agricultural and Environmental Science, 4(2), 165–171.

Khan, M. A., Khan, S., & Mushtaq, S. (2009). Energy and economic efficiency analysis of rice and cotton production in china. Sarhad Journal of Agriculture, 25(2), 291–300.

Khoshnevisan, B., Rafiee, S., & Mousazadeh, H. (2014a). Application of multi-layer adaptive neuro-fuzzy inference system for estimation of greenhouse strawberry yield. Measurement, (47), 903–910.

Khoshnevisan, B., Bolandnazar, E., Shamshirband, S., Shariati, H. M., Anuar, N. B., & Mat Kiah, M. L. (2015). Decreasing environmental impacts of cropping systems using life cycle assessment (LCA) and multi-objective genetic algorithm. Journal of Cleaner Production, 86, 67–77. doi:10.1016/j.jclepro.2014.08.062

Khoshnevisan, B., Rafiee, S., Omid, M., & Mousazadeh, H. (2014b). Prediction of potato yield based on energy inputs using multi-layer adaptive neuro-fuzzy inference system. Measurement, (47), 521–530.

Khoshnevisan, B., Rafiee, S., Omid, M., Mousazadeh, H., & Rajaeifar, M. A. (2014c). Application of artificial neural networks for prediction of output energy and GHG emissions in potato production in Iran. Agricultural Systems, (123), 120–127.

Khoshnevisan, B., Rafiee, S., Omid, M., Yousefi, M., & Movahedi, M.

(2013). Modeling of energy consumption and GHG (greenhouse gas) emissions in wheat production in Esfahan province of Iran using artificial neural networks. Energy, (52), 333–338.

Khoshnevisan, B., Shariati, H. M., Rafiee, S., & Mousazadeh, H. (2014d). Comparison of energy consumption and GHG emissions of open field and greenhouse strawberry production. Renewable and Sustainable Energy Reviews, 29(C), 316–324.

Kizilaslan, H. (2009). Input--output energy analysis of cherries production in Tokat Province of Turkey. Applied Energy, 86(7–8), 1354–1358.

Koga, N., Sawamoto, T., & Tsuruta, H. (2006). Life cycle inventory-based analysis of greenhouse gas emissions from arable land farming systems in Hokkaido, northern Japan. Soil Science and Plant Nutrition, 52(4), 564–574. doi:10.1111/j.1747-0765.2006.00072.x

Komleh, S. H. P., Keyhani, A., Rafiee, S. H., & Sefeedpary, P. (2011). Energy use and economic analysis of corn silage production under three cultivated area levels in Tehran province of Iran. Energy, 36(5), 3335–3341.

Kuesters, J., & Lammel, J. (1999). Investigations of the energy efficiency of the production of winter wheat and sugar beet in Europe. European Journal of Agronomy, 11(1), 35–43.

Kusek, G., Ozturk, H. H., & Akdemir, S. (2016). An assessment of energy use of different cultivation methods for sustainable rapeseed production. Journal of Cleaner Production, (112), 2772–2783.

Kuswardhani, N., Soni, P., & Shivakoti, G. P. (2013). Comparative energy input--output and financial analyses of greenhouse and open field vegetables production in West Java, Indonesia. Energy, (53), 83–92.

Lawal, A. I., Akinoso, R., Olubiyi, M. R., & Olatoye, K. K. (n.d.). Embedded energy of on farm losses and energy analysis for maize production in Nigeria. Transportation, 62(1.75), 109–173.

Lorzadeh, S. H., Mahdavidamghani, A., Enayatgholizadeh, M. R., & Yousefi, M. (2011a). Agrochemical Input Application and Energy Use Efficiency of Maize Production Systems in Dezful, Iran. Middle-East Journal of Scientific Research, 9(2), 153–156.

Lorzadeh, S. H., Mahdavidamghani, A., Enayatgholizadeh, M. R., & Yousefi, M. (2011b). Energy input-output analysis for maize production systems in Shooshtar, Iran. Advances in Environmental Biology, 3641–3645.

Lorzadeh, S. H., Mahdavidamghani, A., Enayatgholizadeh, M. R., & Yousefi, M. (2012). Reasearch of Energy use efficiency for maize production systems in Izeh, Iran. Acta Agriculturae Slovenica, 99(2), 137.

Maqsood, M., Hussain, A., Wajid, S. A., and Akbar, N. (1997). Effect of planting methods and variable rates of nitrogen application on yield and components of yield of rice. Pak. J. Agri. Sci, 34(1-4), 89-93.

MGEDZSJRB, M. B. (2014). Degradation of alizarin yellow R using UV/H2 O2 advanced oxidation process. Environ Sci Technol, 33, 482–489.

Michos, M. C., Mamolos, A. P., Menexes, G. C., Tsatsarelis, C. A., Tsirakoglou, V. M., & Kalburtji, K. L. (2012). Energy inputs, outputs and greenhouse gas emissions in organic, integrated and conventional peach orchards. Ecological Indicators, 13(1), 22–28.

Milovanovic, V., and Smutka, L. (2017). Asian Countries in the Global Rice Market. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 65(2), 679–688. doi:10.11118/actaun201765020679

Mobtaker, H. G., Akram, A., & Keyhani, A. (2012). Energy use and sensitivity analysis of energy inputs for alfalfa production in Iran. Energy for Sustainable Development, 16(1), 84–89.

Mobtaker, H. G., Keyhani, A., Mohammadi, A., Rafiee, S., & Akram, A. (2010). Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. Agriculture, Ecosystems & Environment, 137(3–4), 367–372.

Mohammadi, A., & Omid, M. (2010). Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. Applied Energy, 87(1), 191–196.

Mohammadi, A., Rafiee, S., Jafari, A., Dalgaard, T., Knudsen, M. T., Keyhani, A., Hermansen, J. E. (2013). Potential greenhouse gas emission reductions in soybean farming: a combined use of Life Cycle Assessment and Data Envelopment Analysis. Journal of Cleaner Production, 54, 89–100. doi:10.1016/j.jclepro.2013.05.019

Mohammadi, A., Rafiee, S., Mohtasebi, S. S., Avval, S. H. M., & Rafiee, H. (2011). Energy efficiency improvement and input cost saving in kiwifruit production using Data Envelopment Analysis approach. Renewable Energy, 36(9), 2573–2579.

Mohammadi, A., Rafiee, S., Mohtasebi, S. S., & Rafiee, H. (2010). Energy inputs--yield relationship and cost analysis of kiwifruit production in Iran. Renewable Energy, 35(5), 1071–1075.

Mohammadi, A., Tabatabaeefar, A., Shahin, S., Rafiee, S., & Keyhani, A. (2008). Energy use and economical analysis of potato production in Iran a case study: Ardabil province. Energy Conversion and

Management, 49(12), 3566–3570. . https://doi.org/10.1016/j.enconman.2008.07.003

Mohammadi, A., Rafiee, S., Jafari, A., Keyhani, A., & Shahriari, A. (2010.). Investigation of Water and Energy Productivity for Potato Production under Different Irrigated Systems in Iran. Proceedings of International Agricultural Engineering Conference 2010.

Mousavi-Avval, S. H., Rafiee, S., & Jafari, A. (2011.). An analysis of energy use efficiency of soybean production under different farming technologies. Jordan International Energy Conference 2011. Energy,

Mousavi-Avval, S. H., Rafiee, S., Jafari, A., & Mohammadi, A. (2011a). Energy flow modeling and sensitivity analysis of inputs for canola production in Iran. Journal of Cleaner Production, 19(13), 1464–1470.

Mousavi-Avval, S. H., Rafiee, S., Jafari, A., & Mohammadi, A. (2011b). Optimization of energy consumption for soybean production using Data Envelopment Analysis (DEA) approach. Applied Energy, 88(11), 3765–3772.

Mousavi-Avval, S. H., Rafiee, S., & Mohammadi, A. (2011). Optimization of energy consumption and input costs for apple production in Iran using data envelopment analysis. Energy, 36(2), 909–916.

Mousavi-Avval, S. H., Rafiee, S., Sharifi, M., Hosseinpour, S., Notarnicola, B., Tassielli, G., & Renzulli, P. A. (2017). Application of multi-objective genetic algorithms for optimization of energy, economics and environmental life cycle assessment in oilseed production. Journal of Cleaner Production, 140, 804–815.

Mohseni, P., Borghei, A. M., & Khanali, M. (2018). Coupled life cycle assessment and data envelopment analysis for mitigation of environmental impacts and enhancement of energy efficiency in grape production. Journal of Cleaner Production, 197, 937–947. doi:10.1016/j.jclepro.2018.06.243

Muazu, A., Yahya, A., Ishak, W. I. W., & Khairunniza-Bejo, S. (2015). Energy audit for sustainable wetland paddy cultivation in Malaysia. Energy, 87, 182–191. https://doi:10.1016/j.energy.2015.04.066

Muazu, A., Yahya, A., Ishak, W. I. W., & Khairunniza-Bejo, S. (2014a). Machinery Utilization and Production Cost of Wetland, Direct Seeding Rice Cultivation in Malaysia. Agriculture and Agricultural Science Procedia, 2, 361–369. doi:10.1016/j.aaspro.2014.11.050

Muazu, A., Yahya, A., Ishak, W. I. W., & Khairunniza-Bejo, S. (2014b). Yield Prediction Modeling Using Data Envelopment Analysis Methodology for Direct Seeding, Wetland Rice Cultivation. Agriculture and Agricultural Science Procedia, 2, 181–190.

doi:10.1016/j.aaspro.2014.11.026

Murad, M.W., Mustapha, N.H.N. and Siwar, C., 2008. Review of Malaysian Agricultural Policies with Regards to Sustainability. American Journal of Environmental Sciences, 4: 608-614.

Murumkar, R. P., Dongarwar, U. R., Phad, D. S., Borkar, B. Y., and Pisalkar, P. S. (2014). Performance testing of four row self propelled rice transplanter. International Journal of Science, Environment and Technology, 3(6), 2015-2019.

Nabavi-pelesaraei, A., Abdi, R., & Rafiee, S. (2014). Applying artificial neural networks and multi-objective genetic algorithm to modeling and optimization of energy inputs and greenhouse gas emissions for peanut production. International Journal of Biosciences (IJB), 4(7), 170–183. https://doi.org/10.12692/ijb/4.7.170-183

Nabavi-Pelesaraei, A., Abdi, R., & Rafiee, S. (2016). Neural network modeling of energy use and greenhouse gas emissions of watermelon production systems. Journal of the Saudi Society of Agricultural Sciences, 15(1), 38–47. doi:10.1016/j.jssas.2014.05.001

Nabavi-Pelesaraei, A., Abdi, R., Rafiee, S., & Mobtaker, H. G. (2014). Optimization of energy required and greenhouse gas emissions analysis for orange producers using data envelopment analysis approach. Journal of Cleaner Production, 65, 311–317. doi:10.1016/j.jclepro.2013.08.019.

Nabavi-Pelesaraei, A., Hosseinzadeh-Bandbafha, H., Qasemi-Kordkheili, P., Kouchaki-Penchah, H., & Riahi-Dorcheh, F. (2016). Applying optimization techniques to improve of energy efficiency and GHG (greenhouse gas) emissions of wheat production. Energy, 103(C), 672–678.

Nabavi-Pelesaraei, A., Rafiee, S., Mohtasebi, S. S., Hosseinzadeh-Bandbafha, H., & Chau, K. (2018). Integration of artificial intelligence methods and life cycle assessment to predict energy output and environmental impacts of paddy production. Science of the Total Environment, 631-632, 1279–1294. . doi:10.1016/j.scitotenv.2018.03.088

Nabavi-Pelesaraei, A., Sadeghzadeh, A., Payman, M. H., & Mobtaker, H. G. (2013). An analysis of energy use, CO2 emissions and relation between energy inputs and yield of hazelnut production in Guilan province of Iran. International Journal of Advanced Biological and Biomedical Research, 1(12), 1601–1613.

Nabavi Pelesaraei, A., Shaker Koohi, S., & Bagher Dehpour, M. (2013). Modeling and optimization of energy inputs and greenhouse gas emissions for eggplant production using artificial neural network and multi-objective genetic algorithm. International Journal of Advanced Biological and Biomedical Research, 1(11), 1478–1489.

Naderloo, L., Alimardani, R., Omid, M., Sarmadian, F., Javadikia, P., Torabi, M. Y., & Alimardani, F. (2012). Application of ANFIS to predict crop yield based on different energy inputs. Measurement, 45(6), 1406–1413.

Najim, M. M. M., Lee, T. S., Haque, M. A., and Esham, M. (2007). Sustainability of rice production: a Malaysian perspective. Journal of Agricultural Sciences, 3(1), 1. doi:10.4038/jas.v3i1.8138

Najim, M. M. M., Haque, M. A., Bockari-Gevao, S. M., & others. (2010). Irrigation energy consumption in a tropical lowland rice field. Journal of Agricultural Sciences (Sri Lanka), 5(1), 1–8.

Namdar, M., & Ali Asadi. (2011). Modeling Energy Flow for Orange Production in Iran Majid, Energy, 1(1), 131–139.

Nassiri, S. M., & Singh, S. (2009). Study on energy use efficiency for paddy crop using data envelopment analysis (DEA) technique. Applied Energy, 86(7-8), 1320–1325. doi:10.1016/j.apenergy.2008.10.007

Norsida, M., & Sami, I. S., (2009). Off-farm employment participation among rice farmers in the Muda Agricultural Development Authority and Kemasin Semerak granary areas of Malaysia. Asia-Pacific Development," Dev J., Asia-Pacific, 2, 141-153.

Omid, M., Ghojabeige, F., Delshad, M., & Ahmadi, H. (2011). Energy use pattern and benchmarking of selected greenhouses in Iran using data envelopment analysis. Energy Conversion and Management, 52(1), 153–162.

Ozkan, B., Akcaoz, H., & Fert, C. (2004). Energy input--output analysis in Turkish agriculture. Renewable Energy, 29(1), 39–51.

Ozkan, B., Akcaoz, H., & Karadeniz, F. (2004). Energy requirement and economic analysis of citrus production in Turkey. Energy Conversion and Management, 45(11–12), 1821–1830.

Ozkan, B., Ceylan, R. F., & Kizilay, H. (2011a). Comparison of energy inputs in glasshouse double crop (fall and summer crops) tomato production. Renewable Energy, 36(5), 1639–1644.

Ozkan, B., Ceylan, R. F., & Kizilay, H. (2011b). Energy inputs and crop yield relationships in greenhouse winter crop tomato production. Renewable Energy, 36(11), 3217–3221.

Ozkan, B., Fert, C., & Karadeniz, C. F. (2007). Energy and cost analysis for greenhouse and open-field grape production. Energy, 32(8), 1500–

1504.

Ozkan, B., Kurklu, A., & Akcaoz, H. (2004). An input--output energy analysis in greenhouse vegetable production: a case study for Antalya region of Turkey. Biomass and Bioenergy, 26(1), 89–95.

Ozturk, H. H., Ekinci, K., & Barut, Z. B. (2006). Energy analysis of the tillage systems in second crop corn production. Journal of Sustainable Agriculture, 28(3), 25–37.

Pahlavan, R., Omid, M., & Akram, A. (2012). Energy input--output analysis and application of artificial neural networks for predicting greenhouse basil production. Energy, 37(1), 171–176.

Patel, P. G., Bhut, A. C., & GUPTA, P. (2014). Energy Requirement for Kharif Maize Cultivation in Panchmahal District of Gujarat. Journal of AgriSearch, 1(3), 168–172.

Patel, P. G., Rangapara, D., Bhut, A. C., & others. (2017). Energy requirement for Kharif maize cultivation in Panchmahal district of Gujarat. International Journal of Agricultural Engineering, 10(1), 146–151.

Pathak, H., & Wassmann, R. (2007). Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of technical coefficients. Agricultural Systems, 94(3), 807–825. doi:10.1016/j.agsy.2006.11.015

Patil, S. L., Mishra, P. K., Loganandhan, N., Ramesha, M. N., & Math, S. K. N. (2014). Energy, economics, and water use efficiency of chickpea (Cicer arietinum L.) cultivars in Vertisols of semi-arid tropics, India. Current Science, 107(4), 656.

Pellizzi, G. (1992). Use of energy and labor in Italian agriculture. Journal of Agricultural Engineering Research, 52, 111–119. doi:10.1016/0021-8634(92)80054-v

Pimentel, D., Berardi, G., & Fast, S. (1983). Energy efficiency of farming systems: organic and conventional agriculture. Agriculture, Ecosystems & Environment, 9(4), 359–372.

Pio Lopez, G., Economic reforms for rice sub-sector, The Star Online, Retrieved from:http://biz.thestar.com.my/news/story.asp?file=/2007/6/25/business/18087959&sec=business (2007).

Pirdashti, H., Pirdashti, M., Mohammadi, M., Baigi, M. G., & Movagharnejad, K. (2015). Efficient use of energy through organic rice--duck mutualism system. Agronomy for Sustainable Development, 35(4), 1489–1497.

Pishgar-Komleh, S. H., Ghahderijani, M., & Sefeedpari, P. (2012). Energy consumption and CO2 emissions analysis of potato production based on different farm size levels in Iran. Journal of Cleaner Production, 33, 183–191. doi:10.1016/j.jclepro.2012.04.008

Pishgar-Komleh, S. H., Omid, M., & Heidari, M. D. (2013). On the study of energy use and GHG (greenhouse gas) emissions in greenhouse cucumber production in Yazd province. Energy, 59, 63–71. doi:10.1016/j.energy.2013.07.037

Pishgar-Komleh, S. H., Sefeedpari, P., & Rafiee, S. (2011). Energy and economic analysis of rice production under different farm levels in Guilan province of Iran. Energy, 36(10), 5824–5831. https://doi.org/10.1016/j.energy.2011.08.044

Poungchompu, S., & Chantanop, S. (2016). Economic Aspects of Rice Combine Harvesting Service for Farmer in Northeast Thailand. Asian Social Science, 12(8), 201. doi:10.5539/ass.v12n8p201

Raheli, H., Rezaei, R. M., Jadidi, M. R., & Mobtaker, H. G. (2017). A two-stage DEA model to evaluate sustainability and energy efficiency of tomato production. Information Processing in Agriculture, 4(4), 342–350. doi:10.1016/j.inpa.2017.02.004

Rafiee, S., Avval, S. H. M., & Mohammadi, A. (2010). Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy, 35(8), 3301–3306.

Rahman, S., Hasan, & M. K. (2014). Energy productivity and efficiency of wheat farming in Bangladesh. Energy, 66(C), 107–114.

Ramedani, Z., Rafiee, S., & Heidari, M. D. (2011). An investigation on energy consumption and sensitivity analysis of soybean production farms. Energy, 36(11), 6340–6344.

Ram, H., Singh, J. P., Bohra, J. S., Singh, R. K., and Sutaliya, J. M. (2014). Effect of seedlings age and plant spacing on growth, yield, nutrient uptake and economics of rice (Oryza sativa) genotypes under system of rice intensification. Indian Journal of Agronomy, 59(2), 256-260.

Rani, P. L., Yakadri, M., Mahesh, N., & Bhatt, P. S. (2016). Energy usage and economic analysis of cotton under various weed management practices. Indian Journal of Weed Science, 48(1), 99–101.

Rasouli, M., Namdari, M., & Mousavi-Avval, S. H. (2014). Modeling and analysis of energy efficiency in grape production of Iran. Journal of Agricultural Technology, 10(3), 517–532.

Rathke, G.-W., Wienhold, B. J., Wilhelm, W. W., & Diepenbrock, W. (2007). Tillage and rotation effect on corn–soybean energy balances in eastern Nebraska. Soil and Tillage Research, 97(1), 60–70. doi:10.1016/j.still.2007.08.008

Royan, M., Khojastehpour, M., Emadi, B., & Mobtaker, H. G. (2012). Investigation of energy inputs for peach production using sensitivity analysis in Iran. Energy Conversion and Management, (64), 441–446.

Sahu, G. ., Burman, M., Nair, S. K., Sarawgi, A. K., & Rao, R. K. (2018). Genetic Behaviour of Awning Character in Rice (Oryza sativa L.). International Journal of Current Microbiology and Applied Sciences, 7(05), 490–493. doi:10.20546/ijcmas.2018.705.061

Salami, P., & Ahmadi, H. (n.d.). Energy inputs and outputs in a chickpea production system in Kurdistan, Iran. African Crop Science Journal, 18(2), 51–57.

Salami, P., Ahmadi, H., & Keyhani, A. (2010a). Energy use and economic analysis of strawberry production in Sanandaj zone of Iran. Biotechnol. Agron. Soc. Environ, 14(4), 653–658.

Salami, P., Ahmadi, H., & Keyhani, A. (2010b). Estimating the Energy Indices and Profitability of Strawberry Production in Kamyaran Zone of Iran. Energy, 1, 1.

Samavatean, N., Rafiee, S., Mobli, H., & Mohammadi, A. (2011). An analysis of energy use and relation between energy inputs and yield, costs and income of garlic production in Iran. Renewable Energy, 36(6), 1808–1813.

San-oh, Y., Mano, Y., Ookawa, T., and Hirasawa, T. (2004). Comparison of dry matter production and associated characteristics between direct-sown and transplanted rice plants in a submerged rice field and relationships to planting patterns. Field Crops Research, 87(1), 43–58. doi:10.1016/j.fcr.2003.09.004

Sartori, L., Basso, B., Bertocco, M., & Oliviero, G. (2005). Energy use and economic evaluation of a three year crop rotation for conservation and organic farming in NE Italy. Biosystems Engineering, 91(2), 245–256.

Sauglam, C., Tobi, I., Küp, F., & Çevik, M. Y. (2012). An input-output energy analysis in pistachio nut production: A case study for Southeastern Anotolia Region of Turkey. African Journal of Biotechnology, 11(8), 1868–1871.

Shahamat, E. Z., Asoodar, M. A., Marzban, A., & Abdeshahi, A. (2013). Energy use and economical analysis of sugarcane production in Iran a case study: Debel Khazaeei agro-industry. International Journal of Agriculture and Crop Sciences, 5(3), 249.

Shahan, S., Jafari, A., Mobli, H., Rafiee, S., & Karimi, M. (2008). Effect of

Farm Size on Energy Ratio for Wheat Production : A Case Study from Ardabil Province of Iran. Energy, 3(4), 604–608. Retrieved from http://www.ijat-aatsea.com/pdf/JUNE_v4_n1_08/IJAT2008_07_Karimi.pdf

Shahzad, M., Farooq, M., Jabran, K., & Hussain, M. (2016). Impact of different crop rotations and tillage systems on weed infestation and productivity of bread wheat. Crop Protection, (89), 161–169.

Shamshirband, S., Khoshnevisan, B., Yousefi, M., Bolandnazar, E., Anuar, N. B., Abdul Wahab, A. W., & Khan, S. U. R. (2015). A multi-objective evolutionary algorithm for energy management of agricultural systems - A case study in Iran. Renewable and Sustainable Energy Reviews, 44, 457–465. doi:10.1016/j.rser.2014.12.038

Singh, G. (2006). Estimation of a Mechanisation Index and Its Impact on Production and Economic Factors—a Case Study in India. Biosystems Engineering, 93(1), 99–106. doi:10.1016/j.biosystemseng.2005.08.003

Singh, H., Mishra, D., Nahar, N. M., & Ranjan, M. (2003). Energy use pattern in production agriculture of a typical village in arid zone India: Part II. Energy Conversion and Management, 44(7), 1053–1067. https://doi.org/10.1016/S0196-8904(02)00115-2.

Singh, P., Singh, G., & Sodhi, G. P. S. (2019). Energy auditing and optimization approach for improving energy efficiency of rice cultivation in south-western Punjab, India. Energy. doi:10.1016/j.energy.2019.02.169

Smith, J., Fukai, S., and Mitchell, J. (2012, January). Rice grain yield-a comparison between direct seeding and transplanting in Lao PDR. In Capturing opportunities and overcoming obstacles in Australian agronomy. Proceedings of 16th Australian Agronomy Conference 2012, 14-18 October 2012, Armidale, New South Wales, Australia. Australian Society of Agronomy Inc.

Snyder, C. S., Bruulsema, T. W., Jensen, T. L., & Fixen, P. E. (2009). Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agriculture, Ecosystems & Environment, 133(3-4), 247–266. doi:10.1016/j.agee.2009.04.021

Soltanpanahi, S., Prakash Kammardi, T. N., & Ghaderzadeh, H. (2013). Analysis of input-output energy use in Sugar Beet production in Iran. World Applied Sciences Journal, 28(9), 1252–1261.

Soni, P., & Soe, M. N. (2015). Energy balance and energy economic analyses of rice production systems in Ayeyarwaddy Region of Myanmar. Energy Efficiency, 9(1), 223–237. doi:10.1007/s12053-015-9359-x

SSiwar, C., Diana Mohd Idris, N., Yasar, M., and Morshed, G. (2014). Issues and Challenges Facing Rice Production and Food Security in the Granary Areas in the East Coast Economic Region (ECER), Malaysia. Research Journal of Applied Sciences, Engineering and Technology, 7(4), 711–722. doi:10.19026/rjaset.7.307

Strapatsa, A. V, Nanos, G. D., & Tsatsarelis, C. A. (2006). Energy flow for integrated apple production in Greece. Agriculture, Ecosystems & Environment, 116(3–4), 176–180.

Su, M., Chen, C., & Yang, Z. (2016). Urban energy structure optimization at the sector scale: considering environmental impact based on life cycle assessment. Journal of Cleaner Production, 112, 1464–1474. doi:10.1016/j.jclepro.2015.01.059

Suleiman, U. H., Abdullah, A. M., Shamsudin, M. N., and Mohamed, Z. A. (2014). Time series econometric estimation of supply equation for Malaysian rice sector. Asian Journal of Empirical Research, 4(9), 455-467.

Tabatabaie, S. M. H., Rafiee, S., Keyhani, A., & Heidari, M. D. (2013). Energy use pattern and sensitivity analysis of energy inputs and input costs for pear production in Iran. Renewable Energy, 51, 7–12.

Tahir, A., Khan, F., & Ejaz, K. H. (2003). Techno–Economic Feasibility of Combine Harvester (Class Denominator)–A Case Study. International Journal of Agriculture and Biology, 5(1), 57-60. http://www.ijab.org.

Taki, M., Ajabshirchi, Y., Mobtaker, H. G., & Abdi, R. (2012). Energy consumption, input-output relationship and cost analysis for greenhouse productions in Esfahan province of Iran. American Journal of Experimental Agriculture, 2(3), 485–501.

Toma, E., Dobre, C., Dona, I., & Cofas, E. (2015). DEA Applicability in Assessment of Agriculture Efficiency on Areas with Similar Geographically Patterns. Agriculture and Agricultural Science Procedia, 6, 704–711. doi:10.1016/j.aaspro.2015.08.127

Toriman, M. E., & Mokhtar, M. (2012). Irrigation: Types, Sources and Problems in Malaysia. In Irrigation Systems and Practices in Challenging Environments. Intech. https://www.intechopen.com

Tsatsarelis, C. A. (1993). Energy inputs and outputs for soft winter wheat production in Greece. Agriculture, Ecosystems & Environment, 43(2), 109–118.

Unakitan, G., Hurma, H., & Yilmaz, F. (2010). An analysis of energy use efficiency of canola production in Turkey. Energy, 35(9), 3623–3627.

Uzunoz, M., Akcay, Y., & Esengun, K. (2008). Energy input-output analysis of sunflower seed (Helianthus annuus L.) oil in Turkey. Energy Sources, Part B, 3(3), 215–223.

Veerangouda, M., Sushilendra, S., Prakash, K. V., & Anantachar, M. (2010). Performance evaluation of tractor operated combine harvester. Karnataka Journal of Agricultural Sciences, 23(2), 282-285. https://www.cabdirect.org/cabdirect/abstract/20103243108

Veiga, J. P. S., Romanelli, T. L., Gimenez, L. M., Busato, P., & Milan, M. (2015). Energy embodiment in Brazilian agriculture: an overview of 23 crops. Scientia Agricola, 72(6), 471-477.

Wang, D., Chen, S., Wang, Z., Ji, C., Xu, C., Zhang, X., and Chauhan, B. S. (2014). Optimizing Hill Seeding Density for High-Yielding Hybrid Rice in a Single Rice Cropping System in South China. PLoS ONE, 9(10), e109417. doi:10.1371/journal.pone.0109417

Yuan S, Peng S. Input-output energy analysis of rice production in different crop management practices in central China. Energy 2017;141:1124e32. https://doi.org/10.1016/j.energy.2017.10.007

Younas, M., Abdul Rehman, M., Hussain, A., Ali, L., and Qadir Waqar, M. (2015). Economic Comparison of Direct Seeded and Transplanted Rice: Evidences From Adaptive Research Area of Punjab Pakistan. Asian J Agri Biol, 4(1), 1–7.

Younas, M., Rehman, M. A., Hussain, A., Ali, L., and Waqar, M. Q. (2016). Economic Comparison of Direct Seeded and Transplanted Rice: Evidences from Adaptive Research Area of Punjab Pakistan. Asian J Agri Biol, 4(1), 1-7

Yousefi, M., Damghani, A. M., & Khoramivafa, M. (2014). Energy consumption, greenhouse gas emissions and assessment of sustainability index in corn agroecosystems of Iran. Science of the Total Environment, (493), 330–335.

Yousefi, M., Darijani, F., & Jahangiri, A. A. (2012). Comparing energy flow of greenhouse and open-field cucumber production systems in Iran. African Journal of Agricultural Research, 7(4), 624–628.

Yousefi, M., & Mohammadi, A. (2011). Economical analysis and energy use efficiency in alfalfa production systems in Iran. Scientific Research and Essays, 6(11), 2332–2336.

Zahedi, M., Eshghizadeh, H. R., & Mondani, F. (2013). Energy use efficiency and economical analysis in cotton production system in an arid region: A case study for Isfahan province, Iran. International Journal of Energy Economics and Policy, 4(1), 43–52.