Annals of Agri-Bio Research **28** (2): 472-480, 2023

Impact Score : 0.28 (Scopus)

Optimizing Energy Consumption in Sustainable Wheat Cultivation in Iraq Based on Data Envelopment Analysis and Benchmarking Techniques

ABDULLA AZAWI, THAER TURKY AND MOMTAZ ISAAK*

Agricultural Machinery and Equipment Department, College of Agriculture, Tikrit University, Iraq
**(e-mail: momtaz.isaak@tu.edu.iq; Mobile: 009647830826899)*

(Received: March 03, 2023; Accepted: April 9, 2023)

ABSTRACT

A study was conducted to investigate the energy inputs and outputs of wheat production in Iraq. The main energy inputs for tillage, fertilizing and other operations were human labor, machinery and fuel. These inputs were used at an average energy expenditure of 4132.06 MJ/ha for fertilizing and 1773.87 MJ/ha for harvesting. The majority of the energy inputs came from machinery and fuel, with human labour contributing a small percentage. The average wheat yield in the studied area was 4033.96 kg/ha, with an energy productivity of 0.56 kg/MJ. This meant that for every unit of energy input, 0.56 units of wheat were produced. The net energy gain and energy intensity of the wheat crops were 45, 238.30 and 1.79 MJ/kg, respectively. It was concluded that energy was acquired through wheat production in Iraq. The total energy inputs can be divided into direct, indirect, renewable and non-renewable forms, with the majority being direct and non-renewable. A benchmarking analysis found that the same level of wheat productivity might be reached with fewer energy input and that farmers in the area of study possibly would save 24.14% of human labour input through suitable work planning and administration. Additionally, a benchmarking analysis identified potential reductions in energy usage in machinery and pesticide applications. Farmers also wasted a significant portion of the machinery, chemicals and seeds they used.

Key words: Bio-technique, cultivar, machinery, optimization, wheat

INTRODUCTION

Wheat is a major crop in Iraq that supports its agricultural production and food security. To promote sustainable wheat cultivation, energy consumption intensity optimization should be taken into consideration. Data Envelopment Analysis (DEA), which is a non-parametric method was used to evaluate efficiency from a variety of multiple inputs and outputs, which can be used to measure energy consumption intensity and optimize production (Xu *et al.*, 2020). Combining DEA models with benchmarking techniques can identify higher levels of efficiency potential. Researchers have used these methods to analyze and optimize resource use and energy consumption (Avkiran *et al.*, 2018). The objective of the study to develop new and more effective strategies for sustainable wheat production, which rely on the efficient use of inputs outputs, and energy consumption.

Energy consumption intensity optimization using data envelopment analysis and benchmarking methods is a model used to identify areas of inefficiency and develop strategies to reduce energy consumption and maximize efficiency. However, taking into account the sustainability of wheat cultivation in Iraq, this model may not be the most meaningful approach. To ensure that wheat production in Iraq is sustainable, a wider range of factors needs to be taken into consideration, such as improved access to quality inputs, improved production and harvesting practices, better market access, and improved natural resources management (Ilahi *et al.*, 2019; Karrar, 2019). Therefore, a multi-dimensional, holistic approach is needed to better understand the nuances of wheat production, rather than optimizing energy consumption intensity.

Previous Iraqi administrations recognized agriculture's potential and significance in the country's growth; nevertheless, Iraq's successful agricultural production endeavour was accompanied by increased usage of input, which had increased energy expenditure and a detrimental impact on the environment (Chaloob *et al.*, 2018).

Data Envelopment Analysis (DEA) and benchmarking methods have proven to be effective tools for improving the energy intensity of wheat cultivation from a sustainability perspective in Iraq. The results obtained from these methodologies revealed the potential to reduce energy intensity for wheat production within the country. It is further suggested that similar approaches can be utilized for other agricultural systems, as improvement opportunities for energy efficiency have the potential to not only reduce environmental impact but also enhance economic output. Finally, it is essential to keep in mind that sustainable development is a continuous process and continuous efforts are required to ensure the sustainable production of grains in Iraq. Energy consumption intensity optimization is a term used to explain the amount of energy that is needed to complete a task. For instance, the energy usage of a computer program could be measured and adjusted to use less energy to save energy in the home (Huebner *et al.*, 2021). This energy reduction can be achieved by adjusting the code of the program or by altering the design of the system. By gathering data on the energy consumption of specific tasks, a person can make informed decisions to optimize their energy usage and reduce their expenditure energy (Melhem *et al.*, 2017; Liang *et al.*, 2021). Additionally, increasing the efficiency of energy usage can also be beneficial to the environment. In order to achieve sustainable energy use, individuals can optimize the intensity of their energy consumption (Nakkeeran and Krishnaraj, 2022).

Data Envelopment Analysis (DEA) and benchmarking methods can be essential for sustainable wheat cultivation in Iraq. The ever-increasing need for wheat production, in response to increased food insecurity and population growth, challenges the country's resources and the livelihoods of smallholder farmers. As such, it is critical to measure, compare and modify farming practices to ensure that they are efficient, economically viable and ecologically sustainable (Isaak *et al.*, 2020). DEA and benchmarking methods can help identify the most efficient production methods, minimize input costs and achieve the highest output standards (Ramón *et al.*, 2018). Additionally, these methods can help Iraqi smallholders measure their performance relative to other countries in the region, increasing their competitiveness and ability to export. In this way, DEA and benchmarking can be essential for sustainable wheat cultivation in Iraq.

Data envelopment analysis DEA and benchmarking are valuable tools for optimizing energy consumption, but their implementation in the context of sustainable wheat cultivation in Iraq should not be taken lightly. As such, it is important to consider the potential risks involved in their use, such as limited and potentially misused data sources, incorrect benchmarking and potential results that don't align with the goals of sustainability (Payandeh *et al.*, 2021). Additionally, the effects of their use on sustainability and food insecurity should also be taken into account, as too much reliance on optimization tools may lead to unforeseen consequences (Grote *et al.*, 2021). Overall, while it is important to explore the potential benefits of optimization tools to reduce input costs, their use requires careful consideration of potential consequences. Hence, a study was conducted to investigate the energy inputs and outputs of wheat production in Iraq.

MATERIALS AND METHODS

In this study, 45 wheat-producing farms in Salah Al-Deen Governorate, Iraq, located at 34°27′N 43°35′E, were surveyed using a face-to-face questionnaire approach in 2018. The farms were chosen at random to ensure that the data collected were representative of the population. Furthermore, the survey was conducted by experienced personnel to ensure that the data collected were accurate and reliable.

$$n = \frac{N\,(S \times t)^2}{(N-1)d^2 + (S \times t)^2} \quad ...(1)$$

Where, n was the needed sample size; s was the standard deviation; t was the value at the 95% confidence level (1.96); N was the number of people in the target group; and d was the acceptable error (5%). As a result, the determined sample size for this investigation was 45. The sample size was calculated using a 5% variation from the population mean and 95% confidence intervals.

This section presented the findings from the energy input and output evaluations. The presentation was based on the energy sources utilized by farmers in their activities. The section included energy input results from five operations and six sources. Tillage, seeding, fertilizing, spraying and harvesting were the operations. Human labour, fuel, machinery, fertiliser, chemical, and seed energy were the six sources of energy utilized in agriculture.

A study was conducted on 45 farms to gather data on six different farm inputs (human labour, fuel, machinery, fertilizer, chemicals and seeds) used in operations performed in five fields (tillage, seeding, fertilizing, spraying and harvesting). Conversion coefficients were utilized to convert the data on the farm inputs and wheat yield into energy values. The energy budget for each farm was then calculated in megajoules per hectare, along with total input energy, overall output energy, energy usage efficiency and energy intensity. The methodology for DEA with constant returns to scale from an input perspective was applied to the data from the 45 farms. The excess use of energy inputs on the farms was determined using benchmarks from the DEA. The reference frequency method was used to identify the best methods of growing wheat for less efficient farms to improve wheat productivity.

The information on both the input and output data obtained from the 45 farms was analyzed using DEA to measure a level of efficiency in resource utilization for each farm input. DEA is a performance analysis tool that helps to distinguish between efficient farms and those that are not in their use of resources. The technical efficiency of a farm, which is a measure of how well the farm uses its inputs to produce output, is calculated as the percentage of the amount of measured output to the amount of measured input. This ratio gets from 0 to 1, with a value of 1 indicating efficiency and a value less than 1 indicating inefficiency in resource usage. The CCR model that emphasizes inputs, which is a linear program, was used in this study to compute technical efficiencies.

The purpose of using DEA in this study was to identify the optimal energy inputs for wheat cultivation through the selected farms in Iraq and to use the results to create a predictive model for assessing the efficiency of farmers in wheat farming. By utilizing energy input data from five distinct operations (tillage, seeding, fertilizing, spraying and harvesting) and a single output datum (yield of wheat), the model was executed.

RESULTS AND DISCUSSION

The data collection exercise for energy expenditure associated with wheat cultivation covered five basic operations conducted by farmers in the study area. These operations included tillage, seeding, fertilizing, spraying and harvesting. It is important to note that some of the operations, which are generally conducted by wheat farmers in Iraq, are conducted based on the farmers' preferences. The energy data collected were related to the farm inputs exercised by farmers in executing each of a standard operation, such as the type of fuel used, the number of hours spent on each operation and the amount of labour required. Additionally, the data collected also included information on the environmental impacts of the operations, such as the amount of carbon dioxide emissions generated. These data can be used to assess the sustainability of wheat cultivation in Iraq and to identify potential areas for improvement.

Farmers in the study area conducted tillage operation using two-wheel drive made of medium size with ratings of engine power ranging between 65 and 120 hp as a prime mover. The energy inputs used in performing the tillage operations were human labour, machinery and fuel consumed by the prime movers, essentially during the data collection for tillage operations. All tillage data were collected and analyzed. At first energy analysis was made regarding the share contribution of each or the three energy sources (human labour, machinery and fuel) used in conducting the tillage operations. The energy expenditures due to tillage operations are presented in Table 1. The mean total energy of 1701.31 MJ/ha was expended in performing the tillage operation. Fuel constituted the bulk of the energy expenditure accounting for 93% (1582.29 MJ/ha) of the aggregate energy expenditure. The contributions of machinery and human labour were rather low, pegged at 6.38 and 0.62 %, respectively.

The energy data for the seeding operation covered four farm inputs viz., human, fuel, machinery, and seeds. The energy expenditure data for the seeding operation are presented in Table 1. The mean total energy of 3114.92 MJ/ha was applied through the farmers in the research region. The energy embodied in wheat seeds constituted about 49.64% (1546.15 MJ/

Table 1. Operations-wise energy expenditure in wheat

Operations	HE (MJ/ha)	FE (MJ/ha)	ME (MJ/ha)	FE (MJ/ha)	CE (MJ/ha)	SE (MJ/ha)	Total
Tillage	10.5±0.05	1582.29±39.43	108.52±3.27	Nil	Nil	NIL	1701.31±42.75
Seeding	6.37±0.12	1294.11±33.72	268.29±9.61	Nil	Nil	1546.15±49.95	3114.92±93.4
Fertilizing	5.24±0.20	833.27±27.25	84.61±1.63	3208.94±18.28	Nil	NIL	4132.06±47.36
Spraying	4.37±0.15	954.29±22.56	80.27±1.37	Nil	162.11±3.90	NIL	1201.04±27.98
Harvesting	9.40±0.13	1427.05±35.68	337.42±23.89	Nil	Nil	NIL	1773.87±59.7
Total MJ/ha	35.88±0.66	6091.01±158.64	879.11±39.77	3208.94±18.28	162.11±3.90	1546.15±49.95	11923.2±271.19

ha) of the overall budget of energy due to planting operations. The large confidence interval was recorded in seed energy, highlighting wide variation in the seeding rate adopted by the farmers. The highest and lowest seed energies were 1760.27 and 912.00 MJ/ha representing a seeding rate of about 115.81 and 60 kg/ha, respectively. The combined contributions for human labour, fuel and machinery energy to the total energy accruing to planting operation were 0.20, 41.55, and 8.61%, respectively.

Farmers in the study area applied different types of fertilizers comprising both organic and inorganic, at different rates and intervals. A total number of 1-3 fertilizer applications were made by all farmers in the study area during the season in which the research was conducted. The average fertilizer application frequency per farm was two. The fertilizer application was done mechanically from the collected data. Essentially, the data collection exercise for fertilizing operation covered four energy sources including human labour, fuel, machinery and fertilizer applied. The detailed results for energy fertilizer application are given in Table 1. Summary for the average total expended in performing wheat fertilizing application as indicated in Table 1 demonstrated that energy contained in fertilizer used by the farmers accounted for 34.66% (or 4132.06 MJ/ha) of the average total energy expenditure of 4132.06 MJ/ha which accrued to fertilizing operation. The operational energy due to human labour, fuel and machinery together recorded 22.34% of the total energy used in fertilizing operations. Analysis of the result further showed that human labour energy was not only the least contributor with 5.24 MJ/ha, but as well lagged behind machinery energy expenditure by about 16.15 times. Thus, this indicated the high level of mechanization for the fertilizing operation, which was fully mechanized in Iraq, recorded large confidence interval in fertilizer energy of 47.36 MJ/ha as indicative of huge variation in the use of fertilizer among the farmers.

Chemical application is intended to offer much-needed protection to wheat plants against disease, insect-pests and weed infestations which could hamper yield. In the area under study, farmers used about 15 types of assorted chemical pesticides on their wheat farms. Generally, the farmers used tractor-mounted sprayers in applying pesticides on their farms. The results for the distributed energy expenditure in pesticide applications are illustrated in Table 1. Analysis of the results presented in Table 1 showed that about 13.50% representing 162.11 MJ/ha of the total average energy expended (1201.04 MJ/ha) in conducting pesticide application by the farmers was from embodied energy in the pesticides used.

The harvesting operation of wheat is done mechanically in Iraq. The energy data for the harvesting operation comprised three inputs, namely, human labour, fuel and machinery, used in executing the operation. The findings that pertain to the energy expenditures incurred by the three energy sources employed during harvesting operations are presented in Table 1. Analysis of results indicated that farmers utilized an average total expenditure of energy of 1773.87 MJ/ha in carrying out harvesting operations. Fuel energy accounted for 80.45% of the average total energy budget, with the largest contribution being 1427.05 MJ/ha. The contribution was for human energy 0.53% (9.40 MJ/ha), which was the least contributor.

Accordingly, the energy ratio analysis for the cultivation of one hectare of wheat in the study area is summarized in Table 2. From the table, the average level of wheat yield in the covered area was found to be 4033.96 kg/ha. The average energy productivity of wheat crops was 0.56 kg/MJ. It meant 0.56 units of wheat crop output were acquired per unit of energy. The net energy gain and energy intensity of wheat crops were 45,238.30 MJ/ha and 1.79 MJ/kg for wheat crops. Net energy is positive. Consequently, it can be deduced that in wheat crop production, energy is being acquired. The total mean input of energy in direct, indirect, renewable and non-renewable forms is shown in Table 2. The total consumed energy of input could be categorized into direct energy (51.39%), indirect energy (48.61%), renewable energy (13.27%) and non-renewable energy (86.73%). Based on Table 2, in the area under study, farmers reaped nearly 7.28 times the energy they invested. Farmers produced one kg of wheat by using 1.79 MJ of one of the five sources of energy input utilized in the current study. In other words, farmers produced 560 g of wheat from 1 MJ of energy.

Table 2. Energy ratio analysis

Items	Unit	Value	Percentage
Energy output	MJ/ha	52441.42	-
Energy input	MJ/ha	11923.20	100.00
Direct energy	MJ/ha	6126.89	51.39
Indirect energy	MJ/ha	5796.31	48.61
Renewable energy	MJ/ha	1582.03	13.27
Non-renewable energy	MJ/ha	10341.17	86.73
Energy use efficiency	-	4.40	-
Energy intensity	MJ/kg	1.79	-
Energy productivity	Kg/MJ	0.56	-
Net energy	MJ/ha	40518.22	-

The study revealed that farmers who cultivated more than 17 hectares used a specific average amount of energy input, using five operations and six sources of energy, which were 7203.12 MJ/ha. This was 24.68% higher than the optimal average energy spending of 5458.78 MJ/ha determined out of benchmarking (Table 3). Despite this higher energy input, the similar level of wheat productivity (4.034 t/ha) might be accomplished with a lower average energy input of 1744.34 MJ/ha. The energy inputs for each individual indicated that the necessary decrease ranged from 21.58% for human labour to 28.55% for machinery. The results showed that the farmers were wasting about 25% of the machinery, chemicals and seeds they used. By optimizing their use of these resources, farmers could make significant financial savings and increase their income, improving their overall economic situation. Only about 75% or more of the current financial expenditures on machinery, chemicals and seeds would be needed to meet the nutritional requirements of the wheat plants, resulting in a cost saving of 25% or more.

It is evident from this study that there is potential for the farmers to reduce their energy input and cost of operations while still achieving optimal levels of wheat production. By using the benchmarking methodology to evaluate their operations, farmers can use their energy sources more efficiently, resulting in significant economic savings. Farmers should continue to monitor their energy input levels and make use of energy-saving practices such as reducing their machinery, chemicals and seed procurements so that they can achieve greater financial security.

The study found that (on mean basis) farmers utilized 35.88 MJ/ha of human labour for the five operations studied in the DEA. The optimal amount of human labour, according to the benchmarking results, was 27.218 MJ/ha. This meant that farmers could save 24.14% (8.66 MJ/ha) of the human labour they used by properly planning and managing their work (Table 4). The operation with the greatest potential for reduction in human labour, according to the benchmarking, was tillage. The results indicated that farmers used 3.209 MJ/ha more human labour than was optimal for this operation. This may be due to excess tillage requiring more human labour than would be necessary at optimal levels. The operation with the smallest potential reduction in human labour was spraying, with a calculated surplus usage of 0.974 MJ/ha. While this reduction may be small, it may be worth noting that the fragmented kind of the agricultural land may contribute to the need for more field time for machinery and operators. From this comparison of actual versus optimum energy of human spending, one can conclude that an average human being will

Table 3. Comparison of observed versus optimum energy inputs

Source	Observed	Optimum	Reduction	% Reduction
Human energy	7.183	5.631	1.552	21.58
Fuel energy	1218.202	926.918	291.284	23.42
Machinery energy	127.204	90.537	36.667	28.55
Fertilizer energy	3208.942	2475.822	733.12	22.85
Chemical energy	162.107	118.647	43.46	26.66
Seeds energy	2479.481	1841.229	638.252	25.00
Total	7203.120	5458.78	1744.34	24.68

Table 4. Observed versus optimum mean human energy expenditure-based operations (MJ/ha)

Source	Observed	Optimum	Reduction	% Reduction
Tillage	10.50	7.291	3.209	30.56
Seeding	6.37	5.122	1.248	19.59
Fertilizing	5.24	4.122	1.118	21.34
Spraying	4.37	3.396	0.974	21.29
Harvesting	9.40	7.287	2.113	22.48
Total	35.88	27.218	8.662	24.14

spend far more energy than what is generally recommended. This could be due to lifestyle, diet and other environmental factors. If a person wants to lead a healthier lifestyle, they need to ensure that their daily energy expenditure meets the optimal level for health and wellness. Small changes such as being more physically active throughout the day, consuming a nutritious diet and sticking to a consistent sleep schedule can all help to reduce energy expenditure and ultimately lead to a healthier life.

In wheat cultivation activities, farmers used a mixture of diesel and petrol fuels to power their machinery. The mean noticed energy appeared in fuel was 6091.01 MJ/ha, which was 22.56% higher than the optimal fuel energy demands of 4666.74 MJ/ha, as determined through benchmarking (Table 5). This excess energy value corresponds to 1374.27 MJ/ha of wasted fuel due to the suboptimal use of machinery. The operation with the greatest potential for fuel reduction, according to the benchmarking, was tillage, which required a reduction of 353.67 MJ/ha. This reduction could be achieved by following practices that increase the field capacity of tractors, such as avoiding overlaps, various passes above plowed areas previously, and unnecessary circular turn at corners of plowed fields. The operation with the smallest potential fuel reduction was fertilizing. To optimize fuel use, it may be helpful for tractor operators to adopt driving practices that increase the field capacity of their tractors.

In conclusion, it has been demonstrated that optimum fuel energy expenditure can provide significant cost savings and environmental benefits when compared with observed fuel energy expenditures. Careful analysis of noticed versus optimum fuel energy expenditures has demonstrated that there can be wide variations in the cost and environmental impacts based on having lower fuel efficiency and higher optimum fuel efficiency. Additionally, technological solutions and new regulations can contribute significantly to lowering fuel energy expenditure. Consequently, realizing these cost and environmental benefits requires a comprehensive analysis of both observed and optimum expenditures and cooperation from stakeholders, technological solutions and regulatory bodies.

Table 6 presents the summary statistics for observed and optimal machinery energy expenditure for optimal field performance. The data showed that farmers used an average of 879.11 MJ/ha of machinery energy for the five activities involved in the study. Nevertheless, the benchmarking results indicated that this was 21.99% higher than the optimal amount. This meant that farmers might achieve the similar level of produce with 193.293 MJ/ha less machinery energy expenditure for the five activities. The operation with the greatest potential for reduction in machinery energy was harvesting, which required a reduction of 73.39 MJ/ha (21.75% of existing machinery energy expenditure for the activities). The next highest potential reduction was in the seeding operation, which required a reduction of 57.51 MJ/ha (21.44% of existing machinery energy expenditure for the activities). This

Table 5. Observed versus optimum mean fuel energy-based operations (MJ/ha)

Source	Observed	Optimum	Reduction	% Reduction
Tillage	1582.29	1228.62	353.67	22.35
Seeding	1294.11	1001.90	292.21	22.58
Fertilizing	833.27	635.75	197.52	23.70
Spraying	954.29	737.10	217.19	22.76
Harvesting	1427.05	1113.37	313.68	21.98
Total	6091.01	4716.74	1374.27	22.56

Table 6. Observed versus optimum mean machinery energy-based operations (MJ/ha)

Source	Observed	Optimum	Reduction	% Reduction
Tillage	108.52	83.432	25.09	23.12
Seeding	268.29	210.778	57.51	21.44
Fertilizing	84.61	64.312	20.30	23.99
Spraying	80.27	63.263	17.01	21.19
Harvesting	337.42	264.032	73.39	21.75
Total	879.11	685.817	193.293	21.99

represented 29.75% of the overall surplus machinery energy applied in wheat production. From the comparison of observed versus optimum machinery energy expenditures, it is clear that there is room for improvement in the energy efficiency of machinery. To improve energy efficiency, manufacturers should take necessary steps to reduce wasted energy and energy overhead. These steps could include more careful monitoring and use of machinery, more efficient machinery design and better use of energy-saving technologies. By taking these steps, manufacturers can reduce machinery energy expenditures and help lessen the strain on global energy resources.

Table 7 compares the observed and optimal fertilizer use rates for different elements. The data showed that the mean observed nitrogen use rate was 23.34% higher than the optimal rate determined through benchmarking. The excess usage was 9.644 kg/ha. There was also an excess usage of phosphorus and potassium but to a lesser extent (1.314 and 0.847 kg/ha, respectively).

In conclusion, the comparison of observed versus optimum fertilizer use rates is a complex subject to understand. However, it is clear that by optimizing fertilizer use rates the amount of nutrients given to crops can be optimized, resulting in improved homogeneity of crop growth and increased yield. Ultimately, proper fertilizer use can lead to increased efficiency and environmental benefits, such as reduced runoff of nutrient-rich water and improved nutrient availability for future generations. Therefore, observing and understanding the differences between observed and optimum fertilizer use rates is essential for improving agricultural productivity, sustainability and environmental health.

Table 8 shows that farmers used an average of 10.361 kg/ha of pesticides (including herbicides, insecticides and fungicides) in the study area. However, the benchmarking results revealed that 51% of these pesticides were wasted. This meant that farmers might achieve the similar level of produce using only 5.077 kg/ha of pesticides, rather than the actual mean application rate of 10.361 kg/ha. The greatest potential for reduction in pesticide use was in the category of herbicides, for which a reduction of 51.01% of the current mean application rate was suggested by the benchmarking approach. To optimize the benefits of pesticide use, farmers need to follow the manufacturers' recommendations for mixing and dosage.

The comparison of observed versus optimum chemical use rates provides crucial information for any given chemical application. A thorough review can offer insight into potential unnecessary usage and overuse of a particular chemical which could result in cost savings while maintaining environmental safety and effectiveness. Additionally, this comparison can uncover opportunities for more effective planning to reduce the risk of chemical contamination and promote the overall health of our environment. Therefore, integrating observed versus optimum chemical use rates into standard operations will serve as a valuable tool for maintaining adequate chemical usage concerning the environment.

Table 7. Comparison of observed versus optimum mean fertilizer use rate (kg/ha).

Source	Observed	Optimum	Reduction	% Reduction
Nitrogen	41.318	31.674	9.644	23.34
Phosphate	5.627	4.313	1.314	23.35
Potassium	3.632	2.785	0.847	23.32
Total	50.577	38.772	11.805	23.34

Table 8. Comparison of observed versus optimum chemical used rate (kg/ha)

Source	Observed	Optimum	Reduction	% Reduction
Herbicide	5.170	2.533	2.637	51.01
Insecticide	4.222	2.069	2.153	50.99
Fungicide	0.969	0.475	0.494	50.98
Total	10.361	5.077	5.284	51.00

The mean seeding rate applied by farmers in the region of research was 101.72 kg/ha, which was 25% (51.30 kg/ha) higher than the optimal rate determined through benchmarking. The optimal seeding rate for efficient production, according to the benchmarking results, was 50.42 kg/ha.

Overall, optimizing the number of seeds used for planting has the potential to improve crop yields and reduce production costs. When comparing observed and optimum seed rates, it is essential to consider a variety of factors, including the type of crop, soil and environmental conditions, management practices and the method of production. Careful analysis of these conditions will help to determine the best seed rate which can reduce operating costs and increase profitability. Additionally, it is important to use the correct type of seed, as the wrong number or incorrect quality of seed can significantly impact crop performance. Ultimately, properly analyzing and managing the seed rate is an important factor in crop productivity and profitability.

The inputs of energy used in performing the tillage operations are human labour, machinery and fuel consumed by the prime movers, essentially during the data collection for tillage operation. The contributions of machinery and human labour were pegged at 6.38 and 0.62%, respectively. Farmers in Iraq applied 4132.06 MJ/ha of the average aggregate energy expenditure of fertilizing operations. The fertilizing operation covers four energy sources including human labour, fuel, machinery and fertilizer applied. Analysis of the result further shows that human labour energy is not only the least contributor but also lags behind machinery energy expenditure by about 16.15 times. Iraqi farmers used about 15 types of assorted chemical pesticides on their wheat farms. The energy data for harvesting operations comprised human labour, fuel and machinery used in executing the operation. Farmers utilized an average total expenditure of energy of 1773.87 MJ/ha in carrying out harvesting operations. The average level of wheat yield in the covered zone was 4033.96 kg/ha. The average energy productivity of wheat crops was 0.56 kg/MJ. This meant that 0.56 units of wheat crop output were obtained per unit of energy. The net energy gain and energy intensity of wheat crops were 45,238.30 MJ/ha and 1.79 MJ/kg for wheat crops. Net energy is positive. Consequently, it can be deduced that in wheat crop production, energy is being acquired. The total consumed energy of input could be categorized into direct energy (51.39%), indirect energy (48.61%), renewable energy (13.27%) and non-renewable energy (86.73%). Farmers reaped nearly 7.28 times the energy they invested. Farmers produced one kg of wheat by using 1.79 MJ of one of the five sources of energy input utilized in the current study. In other words, farmers produced 560 g of wheat from 1 MJ of energy. Farmers wasted about one-fourth of the machinery, chemical and seeds they used. By using the benchmarking methodology, it was determined that the average amount of energy required to achieve the best results in wheat production was 5458.78 MJ/ha. However, it was also discovered that the same level of productivity, which was 4.034 t/ha, could be obtained by using a lower amount of energy, specifically 1744.34 MJ/ha. The farmers who cultivated more than 17 ha used the five operations that were evaluated in the DEA to provide the necessary energy input. The study indicated that farmers in the area being examined had the potential to reduce human labour in the listed operations by 8.66 MJ/ha, or approximately 24.14%. This reduction could be achieved by implementing better work planning and management strategies. The tillage operation was identified as having the highest potential for reduction based on the benchmarking results. On average, the energy embodied in fuel that was observed was 22.56% higher than the optimal fuel energy requirement, resulting in an energy value of 1374.27MJ/ha. The study showed that the mean energy consumption per hectare by farmers for the five operations analyzed was 879.11 MJ/ha. The machinery energy usage was about 21.99% higher than the optimum suggested by benchmarking technique. About 37.97% of the required reduction in machinery energy related to the harvesting operation, where the energy used exceeded the optimum requirements by about 73.39%. Seeding is the following operation demanding a substantial machinery energy decrease of about 57.44%. Farmers wasted 51% of the total pesticides used on the wheat crop. The greatest reduction required was in the use of herbicides, for which a demand reduction of up to 51.01% was suggested by benchmarking approach. According to the study, farmers could attain the similar level of produce by using only 5.077 kg/ha of pesticide, which was less than the current average use of 10.361 kg/ha. This could be achieved by using the optimal amount of pesticide. Additionally, the benchmarking results indicated that an efficient production could be achieved by using a mean optimum seeding rate of approximately 50.42 kg/ha.

ACKNOWLEDGMENT

The authors acknowledge the support of the Department of Agricultural Machinery and Equipment, College of Agriculture, Tikrit University, Iraq.

REFERENCES

Avkiran, N. K., Shafiee, M., Saleh, H. and Ghaderi, M. (2018). Benchmarking in the supply chain using data envelopment analysis. *Theor. Econ. Letters* **8**: 2987-3015. *https://doi.org/10.4236/tel.2018.814186.*

Chaloob, I. Z., Ramli, R. and Nawawi, M. K. M. (2018). Measuring economic and environmental efficiency for agricultural zones in Iraq using data envelopment analysis. *Int. J. Infor. Decision Sci.* **10**: 235-248. *https://doi.org/10.1504/IJIDS.2018.093922.*

Grote, U., Fasse, A., Nguyen, T. T. and Erenstein, O. (2021). Food Security and the dynamics of wheat and maize value chains in Africa and Asia. *Fron. Sustain. Food Systems* **4**: 01-17. *https://doi.org/10.3389/fsufs.2020.617009.*

Huebner, G. M., Watson, N. E., Direk, K., McKenna, E., Webborn, E., Hollick, F., Elam, S. and Oreszczyn, T. (2021). Survey study on energy use in UK homes during COVID-19. *Buildings and Cities* **2**: 952-969.

Ilahi, S., Wu, Y., Raza, M. A. A., Wei, W., Imran, M. and Bayasgalankhuu, L. (2019). Optimization approach for improving energy effciency and evaluation of greenhouse gas emission of wheat crop using Data Envelopment Analysis. *Sustainability* (Switzerland) **11**: 01-16. *https://doi.org/10.3390/SU11123409.*

Isaak, M., Yahya, A., Razif, M. and Mat, N. (2020). Mechanization status based on machinery utilization and workers' workload in sweet corn cultivation in Malaysia. *Comp. Elect. Agric.* **169**. *https://doi.org/10.1016/j.compag.2019.105208.*

Karrar, Altaie (2019). Three essays on wheat production efficiency in Iraq: Comparison between mena countries and internal comparison of districts. Colorado State University. *https://mountainscholar.org/handle/10217/195365.*

Liang, B., Wu, D., Wu, P. and Su, Y. (2021). An energy-aware resource deployment algorithm for cloud data centers based on dynamic hybrid machine learning. *Knowledge Based Systems* **222**: 01-9. *https://doi.org/10.1016/j.knosys.2021.107020.*

Melhem, F. Y., Grunder, O., Hammoudan, Z. and Moubayed, N. (2017). Optimization and energy management in smart battery storage system with integration of electric vehicles optimisation et Gestion de l ' Énergie dans une. *Can. J. Elect. Comp. Engin.* **40**: 128-138.

Nakkeeran, G. and Krishnaraj, L. (2022). Optimization and performance analysis of residential building for sustainable energy design through BIM. *J. Engg. Res. Special* **I**: 01-16. *https://doi.org/10.36909/jer.ACMM.16297.*

Payandeh, Z., Jahanbakhshi, A., Mesri-gundoshmian, T. and Clark, S. (2021). Improving energy efficiency of barley production using joint data envelopment analysis (DEA) and life cycle assessment (LCA): Evaluation of greenhouse gas emissions and optimization approach. *Sustainability* **13**: 146-166.

Ramón, N., Ruiz, J. L. and Sirvent, I. (2018). Two-step benchmarking: Setting more realistically achievable targets in DEA. *Expert Systems with Appl.* **92**: 124-131. *https://doi.org/10.1016/j.eswa.2017.09.044.*

Xu, T., You, J., Li, H. and Shao, L. (2020). Energy efficiency evaluation based on data envelopment analysis: A literature review. *Energies* **13**: 48-57. *https://doi.org/10.3390/en13143548.*