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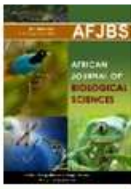

Research Paper **Open Access**

Agro-Environmental Efficiency Assessment of durum wheat cultivation in arid regions, Biskra case (Algeria).

Authors:
Mohamed Ridha Messak[1], Nacer Tarai[1], and Ahmed Nourani[2*]
[1]Affiliation, Laboratory LDEDSPAZA, Department of Agricultural Sciences, Faculty of Exact Sciences, Nature and Life Sciences of University of Biskra E-mail(s): ridha.messak@univ-biskra.dz, ORCID iD: 0000-0003-4018-8813.
[1]Affiliation, Laboratory LDEDSPAZA, Department of Agricultural Sciences, Faculty of Exact Sciences, Nature and Life Sciences of University of Biskra E-mail(s): nacer.tarai@univ-biskra.dz, ORCID iD: 0000-0002-3321-7869.
[2]Affiliation, Scientific and Technical Research Centre for Arid Regions (CRSTRA) E-mail(s): : nourani.ahmed@outlook.com., ORCID iD 0000-0003-3079-9602.
*Corresponding author
E-mail address: nourani.ahmed@outlook.com
Telephone: 002136977000401

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Abstract

This study was conducted in order to assess the energy using, greenhouse gas emissions, and mechanization situation of the Biskra region's durum wheat production system for the 2021–2022 season. Using a questionnaire given to one hundred (100) cereal farmers, the data were gathered. According to the results, te energy input was 41,545.36 $MJ.Ha^{-1}$, and the energy output was 48,086.19 $MJ.Ha^{-1}$. The energy indicator calculations showed that the specific energy, net energy, energy productivity, and energy efficiency were 1.15, 0.08 $kg.MJ^{-1}$, 12.43 $MJ.kg^{-1}$, and + 6,540.83 $MJ.ha^{-1}$, respectively. We were able to determine from these findings that this system is sustainable and productive, meaning it produces more energy than it uses. 1,682.39 kg $CO2eq.Ha^{-1}$ is the total amount of greenhouse gas emissions from the inputs. Additionally, the computations showed that mechanization contributes 2.51% and the mechanization index is almost 71% which show an acceptable level of modernization.

Keywords: Energy using; GHG emissions; mechanization index; wheat cultivation; farming system; sustainability.

1. Introduction:

In Algeria, cereal cultivation holds strategic importance. It occupies 58% of the total agricultural area and generates a production of 5.6 million tons. Among this production, durum wheat stands out, representing 57% of total cereal production, closely followed by barley at 29% (MADR, 2019). Durum wheat is essential for food security in Algeria, as it serves as a basic source of nutrition due to its richness in proteins and essential amino acids. It impacts the national economy by influencing the food trade balance and contributing to the stability of the country (Hadji, 2023). Finally, it plays a role in agricultural sustainability in relation to the management of natural resources (water and soil), the use of inputs, and greenhouse gas emissions.

The cultivation of straw cereals, particularly durum wheat, is very demanding in terms of water; it exceeds 463 mm per hectare (Merrouche, 2015). In the northern regions of Algeria, this crop is primarily rain-fed, whereas in the Saharan regions, it is irrigated through water drilling. For this reason, the cultivation of durum wheat in the Ziban region is considered an important national resource to ensure supply during drought periods, particularly in seeds for supplying other regions.

Production systems provide living organisms with the food and energy essential for their survival. To function effectively, this system uses several production factors, such as human labor, inputs (electricity, fuel, irrigation water, seeds, fertilizers, pesticides, etc.), and soil and harvesting machinery (tractors, combine harvesters, etc.), referred to as inputs. These are considered sources of energy consumed to generate energy, or more specifically, to transform solar energy into chemical energy stored as plant biomass, referred to as outputs, through the mechanism of photosynthesis. However, the irrational use of these factors can pose threats to the health of living organisms and their environment, particularly through the emissions of greenhouse gases (GHGs) such as CO2, CH4, and N2O, and may also affect the sustainability of the production system.

The relationship between agriculture and energy must be integrated into research aimed at evaluating the efficiency and sustainability of production systems. This involves estimating the energy balance, climate impact, and level of mechanization of agricultural practices. The objective is to reduce pressure on non-renewable resources and preserve fossil fuels, while monitoring the effects on health and the environment. It is essential to understand the greenhouse gas emissions associated with different agricultural practices. Studies have shown that conventional agriculture, through methods such as straw burning and intensive tillage, increases carbon dioxide (CO2) emissions and decreases carbon sequestration, thereby contributing to global warming (Khaledian et al., 2006). In contrast, simplified or no-till practices improve emission balances by reducing fuel consumption and increasing carbon storage in the soil (Roger-Estrade et al., 2011).

Several studies have been conducted on agricultural energy flows such as soybean, corn, and wheat production in Italy, rapeseed in Germany, and apricot in Turkey. But none of them worked on the energy flow combined with the greenhouse gas estimation and the state of mechanization in cereal cultivation. In Algeria, few studies have explored this issue and as an example, Nourani et al., 2017a, 2017b, 2019, 2020 and 2021) worked on greenhouse cultivation, Oukil et al., 2022 and 2024, and it is in this context that this work is situated, aiming to evaluate the energy balance, greenhouse gas emissions, and the state of mechanization in durum wheat cultivation systems in the Ziban (Biskra region).

The objective of this research is to analyse energy balance in durum wheat farming systems in the Algerian Ziban region, measure greenhouse gas emissions, and evaluate the level of mechanisation. By understanding these factors, researchers hope to identify opportunities for improving the sustainability and efficiency of durum wheat production in the region. This study will provide valuable insights for farmers, policymakers, and other stakeholders to make informed decisions about agricultural practices and resource management. Ultimately, the goal is to promote sustainable agriculture and reduce the environmental impact of durum wheat farming in Algeria.

2. Materials and Methods

2.1. Presentation of the Biskra study region

The region of Biskra has been known since Roman times as Europe's granary for cereals and other products. Only during the reign of the Turks and the French, it is observed that date palm cultivation expanded at the expense of other crops in the Zibans due to its market value. Cereal cultivation has been practiced for a very long time on the floodplains of rivers in the Biskra region. During the rainy periods, hundreds of hectares are plowed each year.

The wilaya of Biskra is located in the southeastern part of Algeria, 400 km from the capital Algiers, at the foot of the Aurès Mountains, which form the natural border between it and the north. It is located at an altitude of 124m, its latitude is 34.48°N and its longitude is 05.44°E, and it covers an estimated area of 21,509.8 km², comprising 33 municipalities and 12 dairas. It is bordered by the wilaya of Batna to the north, the wilaya of M’sila to the northwest, the wilaya of Khenchela to the northeast, the wilaya of Djelfa to the southwest, the wilaya of El-Oued to the southeast, and the wilaya of Ouargla to the south.

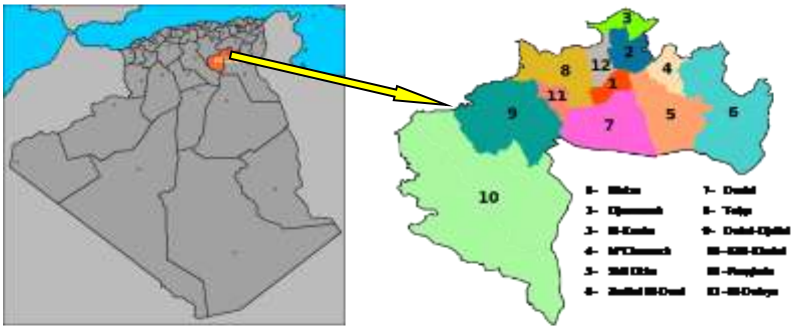

Figure 01: Map of the region of Biskra

The soils of the Biskra region are generally sandy to loamy in texture. Due to the arid climatic conditions and sparse vegetation cover, these soils tend to have low organic matter content. Biskra has a desert climate (BWh), characterized by low annual precipitation and high temperatures. The average yearly rainfall is around 125 mm, with July being the driest month (0 mm) and March recording the highest precipitation (16 mm). This figure provides visual representations of rainfall distribution throughout the year, helping to contextualize the arid conditions of the region.

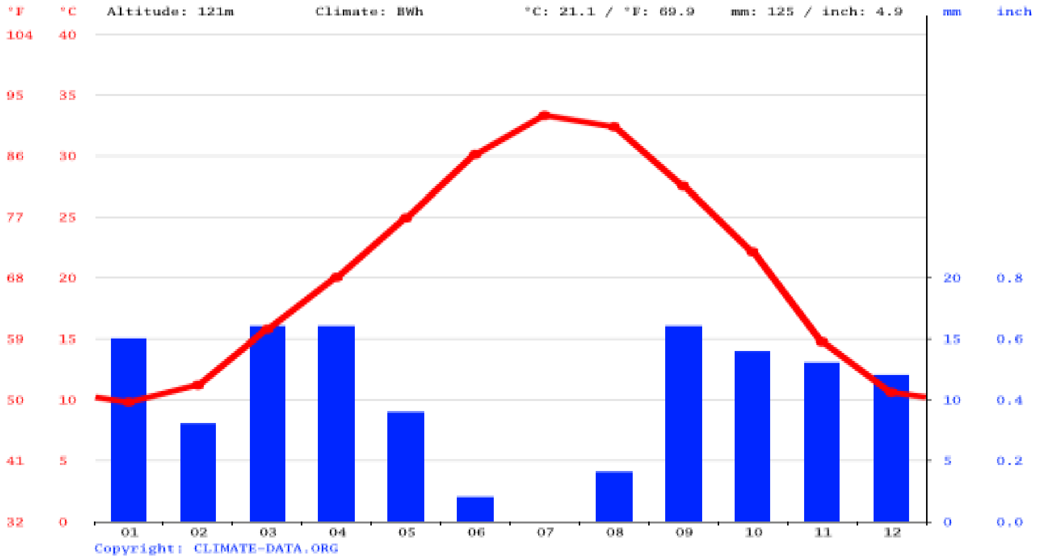

Figure 02: Diagramme ombrothermique of Biskra

2.2. Methodological Framework and Indicator Definitions

2.2.1. Survey Preparation

This study consists of conducting a survey with a sample of all cereal farmers in the Biskra wilaya using a questionnaire during the agricultural season 2021/2022. In Biskra wilaya, there are a total of 1,786 farmers that grow wheat. Given the time and geographical constraints, we were able to complete a sample of 100 wheat farmers. They were chosen at random for this study and represent more than 5% of the maternal population. The investigation was conducted at a 90% confidence level, with the remaining 10% representing acceptable error.

This number of respondents includes all types of production, whether Semolina, Seeds, or Frik (**Frik** (or **freekeh**) is a type of green wheat harvested before fully ripening, then roasted to remove the husks. It is dried and either cracked or used whole. Originating from the Middle East and North Africa, it is commonly used in soups, stews, and grain-based dishes. Frik is high in fiber, protein, and minerals, and is known for its slightly crunchy texture and smoky flavor), distributed across the eleven (11) municipalities that recorded the highest means of durum wheat production in the Biskra province, which are (Elfeidh, Zeribet eloued, M'ziraa, Ain naga, Sidi okba, Elhaouche, Eloutaya, Tolga, Oumahe, Ourlal, and Mlili). This sample is distributed as follows;

- Sixty (60) surveyed Semolina producers
- Twenty (20) surveyed Seed producers
- Twenty (20) surveyed Frik producers.

The questionnaire is composed of three (03) parts which are

- Identification of the operator: including the personal information of the farmer (name, first name, address, level of education…);
- Identification of the farm: including information about the farm (locality, place name, SAT, SAU…);
- Identification of the inputs used and their quantities or volumes of hours used for each (equipment, supplies, irrigation water, and labor…) and on the other hand the outputs harvested and their quantities.

2.2.2. Estimation of Energy flow

The energy analysis method is a tool for calculating the energy inputs and outputs in a farm operation. It applies to most existing animal or plant productions. Obtaining the energy profile of the farm (distribution by categories) allows, by comparison with similar farms, to situate the operation and thus identify areas for improvement through more energy-efficient agricultural practices, and/or by implementing renewable energies as a substitute for fossil or fissile energies.

The calculations were made on the total energy input per unit area (Ha), which constitutes the total energy inputs, namely: human labor, machinery and supplies (seeds, chemical fertilizers, chemical products), irrigation water, electricity, and fuels. The energy output/input ratios of companies involved in durum wheat agriculture.

The energy balance calculations were made to determine the level of productivity and the agricultural sustainability of the durum wheat production system. The units indicated in Table 1 were used to calculate the input/output values of durum wheat production. Previous energy analysis studies (sources) were used when determining the equivalent energy coefficients. By adding the energy equivalents of all the inputs in the unit MJ, the total energy equivalent was found.

Table 1: The units and energy equivalents used in the energy balance of durum wheat production

Input / Output	Unit	Equivalent energy (MJ / Unit)	Source
Input			
Wheat seed	Kg	14.7	Mani, 2007
Engrais chimique			
Azote (N)	Kg	66.14	Mohammadi et al, 2010
Phosphore (P2O5)	Kg	12.44	Mohammadi et al, 2010
Potasse (K2O)	Kg	11.15	Mohammadi et al, 2010
Pesticide			
Herbicide	Kg	310	Saunders et al., 2006
Fungicide	Kg	210	Saunders et al., 2006
Insecticide	Kg	315	Saunders et al., 2006
Electricity	KWh	3.6	Ozkan et al. (2004)
Irrigation water	M^3	1.02	Pimental 2019
Machinery	H	62.70	Singh et al. (2002)
Fuel	L	56.31	Nabavi-Pelesaraei et al. 2016
Human labor	H	1.96	Mani, 2007
Output			

Wheat grain	Kg	14.7	Mani, 2007
Straw	Kg	12.5	Mani, 2007

The energy needs of agriculture are divided into two groups, direct and indirect or renewable and non-renewable (Samavatéen, 2011). The energy efficiency of the agricultural system can be evaluated by the relationship between the energy produced and the energy consumed. (Ghorbani R ,et al,.2001). Based on the energy equivalents of inputs and outputs, the energy efficiency, energy productivity, specific energy, and net energy indices were calculated using the following equations (Rafiee S et al, 2010).

$$\text{Energy efficiency} = \frac{\text{Energy produced (MJ. Ha}^{-1}\text{)}}{\text{Energy consumed (MJ. Ha}^{-1}\text{)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1)$$

$$\text{Energy productivity (kg. MJ}^{-1}\text{)} = \frac{\text{Production (Kg. Ha}^{-1}\text{)}}{\text{Energy consumed (MJ. Ha}^{-1}\text{)}} \ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\text{Specific energy (MJ. kg}^{-1}\text{)} = \frac{\text{Energy consumed (MJ. Ha}^{-1}\text{)}}{\text{Production (Kg. Ha}^{-1}\text{)}} \ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots..... (3)$$

$$\text{Net energy (MJ. Ha}^{-1}\text{)} = \text{Produced energy (MJ. Ha}^{-1}\text{)} - \text{Consumed energy (MJ. Ha}^{-1}\text{)} \ldots (4)$$

2.2.3. Estimation of GHG emission:

Agriculture, akin to every economic sector, contributes to a fraction of greenhouse gas (GHG) emissions in the atmosphere. The main GHG emissions from agriculture come from animals (CH4 and N2O emissions), the various forms of nitrogen involved (direct N2O emissions into the air or via the soil), fertilization, mineralization, fixation, direct gaseous emissions...), and the consumption of direct or indirect energy (CO2 and nitrogen oxides during combustion). The quantification of GHG emissions using unit energy and GHG emission coefficients. All this data comes from the international bibliography on life cycle assessments and eco-balances, as indicated in the table below.

Table 2: The units and CO2 equivalents used in the assessment of GHG emissions from durum wheat production.

Input / Output	Unit	GHG equivalent (Kg CO2eq/unit)	Source
Input			
Chemical fertilizer			
Nitrogen (N)	Kg	4.570	Eren et al, 2019
Phosphorus (P2O5)	Kg	1.180	Eren et al, 2019
Potash (K2O)	Kg	0.640	Eren et al, 2019
Pesticide	Kg	13.900	Eren et al, 2019
Electricity	KWh	0.608	Nabavi-Pelesaraei et al. 2016
Machinery	H	0.071	Eren et al, 2019
Fuel	L	2.760	Eren et al, 2019
Human labor	H	0.700	Eren et al, 2019

2.2.4. Estimation of the state of mechanization

The degree of mechanization, the mechanization index, and the energy input of machines are internationally accepted as indicators of the state of mechanization. (Samavatean et al., 2011).

The degree of mechanization (MD) is the index that examines the quantity in mechanization issues and is defined as the mechanized performances to the total necessary mechanized performances or the area where mechanized performances are applied to the total area.

Specifically, we can consider the degree of mechanization as an index of quantity comparable at different levels of mechanization. This index has a wide application in the growth of mechanization over different years or in comparing the degree of mechanization of various operations, as well as a significant influence on cause analysis.

Mechanization Index (MI): Singh (2006) presented a definition of the mechanization index based on the use of living beings and machines in input energy, which is calculated from the relationship (5).

$$IM = \frac{EMU}{EHU+EAU+EMU} \dots\dots\dots\dots\dots\dots\dots\dots\dots (5)$$

Where IM: Mechanization Index; EMU: energy of machine use; EHU: energy of labor use; EMU: energy of animal power use.

The energy ration of the machines is an index that represents the fraction of the total energy inputs through the various tools and equipment used in different operations for the cultivation of the particular crop. (Yadav et al., 2013). The equation compares the total energy input required for cultivation to the energy consumption of each machine, such as tractors, planters, and harvesters. By calculating the energy ration of machines, farmers can assess the efficiency of their equipment and make informed decisions about resource allocation and management.

This data can also help identify areas where energy-saving measures can be implemented to reduce overall energy consumption and increase sustainability in agriculture.

The energy ration of machines was determined using the following equation (6).

$$MER = \frac{Ed}{Te} \text{.............................} \ (6)$$

Where MER is the ration of machine energy to the total energy input; "Ed" is the energy input through the various machines/tools; and "Te" is the total energy input from human labor, animals, machine/hand tools, seeds, and farmyard manure for wheat production.

3. Results and Discussion

In this section, the main results of our survey will be presented, divided into two parts; the first is on the identification of the surveyed cereal farmers and their agricultural operations, while the second is on the energy balance, greenhouse gas emissions, and the state of mechanization of their durum wheat production systems.

2.3. Identification of the surveyed cereal farmers and their agricultural farms

A. Age of the respondents

The table presents the distribution of farmers according to their age groups.

Table 3: Distribution of respondents by age group

Class (xi)	Workforce (ni)	Frequency (fi)	Cumulative
26 - 33	9	0.09	0.09
34 - 41	12	0.12	0.21
42 - 49	22	0.22	0.43
50 - 57	23	0.23	0.66
58 - 65	11	0.11	0.77
66 - 73	14	0.14	0.91
74 - 81	8	0.08	0.99
82 - 89	1	0.01	1
N	100	1	/

The majority of farmers are in the middle age groups, specifically between 42 and 57 years old, which represent 45% of the total (22% for the 42-49 age group and 23% for the 50-57 age group). The cumulative frequency shows that 66% of farmers are 57 years old or younger, indicating a rather mature agricultural population. The older age groups (58-81 years) represent about 33% of farmers, while farmers over 81 years old are very few, with only 1%. Conversely, the youngest (26-33 years old) represent 9% of the workforce. In summary, the agricultural population is largely concentrated in the middle to advanced age groups, with a low presence of young and very elderly individuals. This lack of talent and knowledge transfer could hinder innovation and growth. Attracting and retaining young farmers while preserving older wisdom is crucial for long-term agricultural sustainability.

B. Production yield of the respondents' farms

The following table presents the distribution of farmers based on yield classes per hectare.

Table 4: Distribution of respondents by class of production yields per hectare of farms

Class (xi)	Workforce (ni)	Frequency (fi)	Cumulative (fcc)
[17 , 20]	8	0.08	0.08
] 20 , 23]	15	0.15	0.23
] 23 , 26]	26	0.26	0.49
] 26 , 29]	18	0.18	0.67
] 29 , 32]	10	0.10	0.77
] 32 , 35]	8	0.08	0.85
] 35 , 38]	5	0.05	0.90
] 38 , 41]	3	0.03	0.93
] 41 , 44]	4	0.04	0.97
] 44 , 47]	3	0.03	1
N	100	1	/

The most represented class is that of yields between 23 and 26 (kg/ha), with 26 farmers, representing 26% of the total, followed by the class between 26 and 29 with 18 farmers (18%). The cumulative frequency shows that 49% of farmers have a yield less than or equal to 26, and 67% have a yield less than or equal to 29. At the other end, classes with higher yields (between 38 and 47) are less frequent, representing 15% of farmers in total. The cumulative frequency reaches 100% for the class]44, 47], indicating that all the farmers fall within this yield range. This distribution shows a concentration of the majority of farmers in the medium yield classes (between 23 and 29), with a gradual decrease in numbers in the higher yield classes.

3.2. Estimation of the energy balance of the durum wheat production system.

A. Energy balance calculations:

The results of the survey on the energy balance of durum wheat production in the Ziban region are based on data collected from the 2021/2022 campaign, from which we took a sample of 100 cereal farmers with a total sown area of 1,554.50 Ha, whose average production was 2,880.93 Kg Ha^{-1}. As presented in Table 5, the results of the energy analysis showed that the total energy consumption by all inputs was 41,545.36 MJ.Ha^{-1} distributed as follows; the largest portion of energy was consumed by electricity with 12,235.83 MJ.Ha^{-1} (29.45%), followed by irrigation water 9,552.32 MJ.Ha^{-1} (23.00%), chemical fertilizers 7,381.13 MJ.Ha^{-1} (19.70%), fuel 7,346.92 MJ.Ha^{-1} (17.68%), seeds 2,683.26 MJ.Ha^{-1} (6.45%), machinery 1,003.5 MJ.Ha^{-1} (2.45%), human labor 373.25 MJ.Ha^{-1} (0.88%), and pesticides 162.97 MJ.Ha^{-1} (0.39%). The output energy was 48,086.19 MJ.Ha^{-1}, of which the durum wheat grains accounted for 42,349.62 MJ.Ha^{-1} (88.07%) and the straw 5,736.57 MJ.Ha^{-1} (11.92%).

Table 5: Energy calculations for durum wheat production

Input / Output	Unit	Equivalent energy (MJ / Unit)	Unit per hectare (unit.Ha¯1)	Energy value (MJ.Ha¯1)	ration (%)
Input					
Wheat seed	Kg	14.7	182.53	2 683.26	6.45
Chemical fertilizers				8 187.31	19.70
Nitrogen (N)	Kg	66.14	115.29	7 625.10	18.35
Phosphorus (P2O5)	Kg	12.44	34.78	432.67	1.04
Potash (K2O)	Kg	11.15	11.62	129.54	0.31
Pesticida				162.97	0.39
Herbicide	Kg	310	0.42	131.22	0.31
Fungicide	Kg	210	0.13	26.48	0.06
Insecticide	Kg	315	0.02	5.27	0.01
Electricity	KWh	3.6	3 398.84	12 235.83	29.45
Irrigation water	M^3	1.02	9 365.02	9 552.32	23.00
Machinery	H	62.70	16.0	1003.5	2.41
Fuel	L	56.31	130.47	7 346.92	17.68
Human labor	H	1.96	190.43	373.25	0.89
Total input				41 545.36	100
Output					
Grain of wheat	Kg	14.7	2 880.93	42 349.62	88.07
Straw	Kg	12.5	458.93	5 736.57	11.92
Total output				48 086.19	100

The input energy can be divided into two groups (direct and indirect) or (renewable et non-renewable). Indirect energy includes: seeds, chemical fertilizers, pesticides, machinery, while direct energy includes: human labor, fuel, electricity, irrigation water. Renewable energy includes: human labor and irrigation water, whereas non-renewable energy includes: machinery, seeds, chemical fertilizers, pesticides, electricity, fuel.

Table 6: Types of energies used in durum wheat production

Type of energy	Energy inputs (MJ.Ha^{-1})	Ration (%)
Direct energy	29 508.32	71.02
Indirect energy	12 037.04	28.97
Total	41 545.36	100
Renewable energy	9 925.57	23.89
Non-renewable energy	31 619.79	76.10
Total	41 545.36	100

As presented in Table 6, the direct energy is 29,508.32 MJ.Ha^{-1} or 71.02%, while the indirect energy is 12,037.04 MJ.Ha^{-1} or 28.97%. Renewable energy is 9,925.57 MJ.Ha^{-1} or 23.89%, while non-renewable energy is 31,619.79 MJ.Ha^{-1} or 76.10%.

B. The indicators of energy balance

The calculations of the energy indicators have demonstrated the following (table 7):

Table 7: Calculations of Energy Indicators for Durum Wheat Production

Indicators	Unit	Values
Production	Kg.Ha-1	3 339.86
Energy consumed	MJ.Ha-1	41 545.36
Energy produced	MJ.Ha-1	48 086.19
Energy efficiency	-	1.15
Energy productivity	Kg. MJ^{-1}	0.08
Specific energy	MJ. Kg^{-1}	12.43
Net energy	MJ.Ha-1	+ 6 540.83

The table 7 presents energy indicators related to durum wheat production. The production is 3,339.86 kg/ha, with an energy consumption of 41,545.36 MJ/ha and an energy production of 48,086.19 MJ/ha. The energy efficiency of 1.15 indicates that for every unit of energy invested, the operation produces 1.15 units of energy, showing a production higher than consumption. The energy productivity of 0.08 kg/MJ shows that approximately 0.08 kg of durum wheat are produced for each megajoule of energy consumed. The specific energy, which is 12.43 MJ/kg, represents the amount of energy required to produce one kilogram of durum wheat. Finally, the net energy of 6,540.83 MJ/ha shows an energy surplus, meaning that the operation produces more energy than it consumes. These indicators demonstrate an overall efficient production from an energy perspective, with a positive yield.

Previously, studies related to wheat production have been conducted. The calculations of the energy produced/consumed ratio yielded the following results (table 8):

Table 8: Studies on Energy Efficiency Calculations

Studies	Production (Kg.Ha^{-1})	Input energy (MJ.Ha^{-1})	Energy output (MJ.Ha^{-1})	ration
Tipi et al. (2009)	4346	20653.54	63686.20	3.09
Shahin et al. (2008)	3675	38356.39	120097.90	3.13
Kardoni et al. (2013)	4285	35605	62989.50	1.76
Karaağaç et al. (2011)	2587.20	16553.94	63686.20	3.09
Moghimi et al. (2013)	5537.50	42998.44	97935.53	2.28

Studies show variability in yields and energy efficiencies. Shahin et al. (2008) and Tipi et al. (2009) present the best energy ratios (above 3), which indicates high efficiency. Kardoni et al. (2013) have a lower ratio, indicating lower energy efficiency despite a relatively high yield. Moghimi et al. (2013) stands out for its highest yield, although its energy efficiency is slightly lower. When comparing our study on durum wheat production with other studies, we observe that our yield of 3,339.86 kg/ha is lower than that of several studies, such as Shahin et al. (2008) with 3,675 kg/ha, Tipi et al. (2009) with 4,346 kg/ha, and Moghimi et al. (2013) which even reach 5,537.50 kg/ha. However, our yield is close to that of Karaağaç et al. (2011) with 2,587.20 kg/ha. In terms of energy consumed (41,545.36 MJ/ha), our study is in the upper range compared to other studies, such as Tipi et al. (2009) with only 20,653.54 MJ/ha, but remains slightly below Moghimi et al. (2013) (42,998.44 MJ/ha). The energy produced in our study is 48,086.19 MJ/ha, which is much lower than studies like Shahin et al. (120,097.90 MJ/ha) and Tipi et al. (63,686.20 MJ/ha). The energy produced/consumed ratio in our study, 1.15, is also lower compared to other studies, such as Shahin et al. and Tipi et al., which show ratios above 3, indicating greater energy efficiency in those other works. Thus, although our system is positive in terms of net energy, it is less efficient than other studies in terms of energy efficiency and yield.

C. Comparison between the energy balances of durum wheat Semolina, Seed, and Frik production.

In comparing the energy balances of durum wheat Semolina, Seed, and Frik production, it is important to consider the various inputs and outputs involved in each process. By analyzing the energy balances of each production process, we can better understand the overall sustainability and efficiency of durum wheat production. In addition, comparing the energy balances of these different stages of production can help identify areas for improvement and optimization in order to reduce energy consumption and environmental impact. By taking a holistic approach to analyzing energy balances, we can make informed decisions on how to make durum wheat production more sustainable and efficient in the long run. Ultimately, this analysis can contribute to the development of more environmentally friendly practices within the agriculture industry.

The results of this comparison are summarized in the following table:

Table 9: Energy estimation of durum wheat semolina, seed, and frik production

Input / Output	Unit	Equivalent energy (MJ / Unit)	Unit per hectare (unit.Ha^{-1})			Energy value (MJ.Ha^{-1})			Ration (%)		
Inputs											
			Semolina	Seeds	Frik	Semolina	Seeds	Frik	Semolina	Seeds	Frik
Wheat seed	Kg	14,7	173,46	200	167,46	2 549,92	2 940,00	2 461,72	6,73	6,29	5,38
Chemical fertilizer			106,97	125,75	130,98	7 645,15	8 865,40	9 229,19	20,19	18,97	20,19
Nitrogen (N)	Kg	66,14	37,06	32,69	26,36	7 074,98	8 316,84	8 662,76	18,69	17,8	18,95
Phosphorus (P2O5)	Kg	12,44	9,79	12,73	21,39	461,04	406,62	327,96	1,21	0,87	0,71
Potash (K2O)	Kg	11,15				109,13	141,94	238,47	0,28	0,3	0,52
Pesticide			0,33	0,58	0,38	129,26	220	148,8	0,34	0,47	0,32
Herbicide	Kg	310	0,12	0,13	0,14	103,22	178,74	118,66	0,27	0,38	0,25
Fungicide	Kg	210	0,05	0,05	-	26,04	26,5	30,14	0,06	0,05	0,06
Insecticida	Kg	315					14,76	-	-	0,03	-
Electricity	KWh	3,6	3 495,75	3 066,67	4 333,01	12 584,72	11 040,00	15 598,85	33,24	23,63	34,13
Irrigation water	M³	1,02	9 429,71	9 213,05	9 618,09	9 618,30	9 397,31	9 810,45	25,40	20,11	21,46
Machinery	H	62,7	15,13	16,25	22,23	948,35	1 018,90	1 394,10	2,50	2,18	3,05
Fuel	L	56,31	71,08	229,01	115,79	4 002,73	12 895,50	6 520,11	10,57	27,6	14,26
Human labor	H	1,96	191,26	173,88	271,29	374,86	340,8	531,73	1,00	0,72	1,16
Total input						37 853,29	46 717,91	45 694,95	100	100	100
output											
Grain of wheat	Kg	14,7	2 817,65	3 030,45	2 628,71	41 419,51	44 547,62	38 642,01	87,51	88	94,01
Straw	Kg	12,5	472,63	486,22	196,65	5 907,82	6 077,70	2 458,13	12,48	12	5,98
Total output						47 327,33	50 625,32	41 100,14	100	100	100

A sample of 60 Semolina producers has been considered with a total sowing area of 895 Ha, whose average production was 2,817.65 Kg Ha^{-1}. The results of the energy analysis showed us, as presented in Table 9, that the total energy consumption was 37,853.29 MJ.Ha^{-1}, distributed as follows: the largest portion of the energy was consumed by electricity 12,584.72 MJ.Ha^{-1} (33.24%), followed by irrigation water 9,618.30 MJ.Ha^{-1} (25.40%), chemical fertilizers 6,895.15 MJ.Ha^{-1} (20.19%), fuel 4,002.73 MJ.Ha^{-1} (10.57%), seeds 2,549.92 MJ.Ha^{-1} (6.73%), machinery 948.35 MJ.Ha^{-1} (2.50%), human labor 374.86 MJ.Ha^{-1} (1.00%), and pesticides 129.26 MJ.Ha^{-1} (0.34%). The output energy was 47,327.33 MJ.Ha^{-1}, of which the durum wheat grains accounted for 41,419.51 MJ.Ha^{-1} (87.51%) and the straw 5,907.82 MJ.Ha^{-1} (12.48%).

Meanwhile, we took as a sample 20 seed multipliers with a total sowing area of 555 hectares, whose average production was 3,030.45 kg per hectare. As presented in the previous table, the results of the energy analysis showed that the total energy consumption by all inputs was 46,717.91 MJ.Ha^{-1} distributed as follows: the largest portion of the energy was consumed by fuel with 12,895.50 MJ.Ha^{-1} (27.60%), followed by electricity. 11,040 MJ.Ha^{-1} (23.63%), irrigation water 9,397.31 MJ.Ha^{-1} (20.11%), chemical fertilizers 7,992.87 MJ.Ha^{-1} (18.97%), seeds 2,940 MJ.Ha^{-1} (6.29%), machinery 1,018.90 MJ.Ha^{-1} (2.18%), human labor 340.80 MJ.Ha^{-1} (0.72%), and pesticides 220 MJ.Ha^{-1} (0.47%). The output energy was 50,625.32 MJ.Ha^{-1}, of which the durum wheat grains accounted for 44,547.62 MJ.Ha^{-1} (88.00%), while the straw accounted for 6,077.70 MJ.Ha^{-1} (12.0%).

At the same time, a sample of 20 durum wheat Frik producers has been taken with a total sown area of 104.55 hectares, whose average production was 2,628.71 kg per hectare. The results of the energy analysis showed us, according to the table above, that the total energy consumption by all inputs was 45,694.95 MJ.Ha^{-1} distributed as follows: the largest portion of energy was consumed by electricity with 15,598.85 MJ.Ha^{-1} (34.13%), followed by irrigation 9,810.45 MJ.Ha^{-1} (21.46%), chemical fertilizers 8,294.50 MJ.Ha^{-1} (20.197%), fuel with 6,520.11 MJ.Ha^{-1} (14.56%), seeds 2,461.72 MJ.Ha^{-1} (5.50%), machinery 1,394.10 MJ.Ha^{-1} (3.05%), human labor 531.73 MJ.Ha^{-1} (1.16%), and pesticides 148.80 MJ.Ha^{-1} (0.32%). The output energy was 41,100.14 MJ.Ha^{-1}, of which the durum wheat grains accounted for 38,642.01 MJ.Ha^{-1} (94.01%) and the straw 2,458.13 MJ.Ha^{-1} (5.98%).

As presented in Table 10, the results of the analyses obtained on the evaluation of the energy balance of durum wheat production and the comparison between the three durum wheat production systems, semolina production, seed production, and Frik production, have shown us that the two production systems of semolina and seeds are productive systems, meaning that these systems produce more energy than they consume.

Table 10: Calculations of energy indicators for semolina, seeds and Frik wheat production

Indicators	Unit	Values		
		semolina	seeds	Frik
Production	$Kg.Ha^{-1}$	3 290.28	3 516.67	2 825.36
Energy consumed	$MJ.Ha^{-1}$	37 853.29	46 717.91	45 694.95
Energy produced	$MJ.Ha^{-1}$	47 327.33	50 625.32	41 100.14
Energy efficiency	-	1.25	1.08	0.90
Energy productivity	$Kg. MJ^{-1}$	0.08	0.07	0.06
Specific energy	$MJ. Kg^{-1}$	11.50	13.28	16.17
Net energy	$MJ.Ha^{-1}$	+ 9 474.04	+ 3 907.41	- 4 594.81

Energy productivity, that is, the productivity of 1 MJ of energy consumed in the semolina production system (0.08 $Kg.MJ^{-1}$), is higher than that of the Seed production system (0.07 $Kg.MJ^{-1}$). However, the results of the energy analysis of Frik's production system have shown us that it is a consumptive system, meaning that the system produces less energy than it consumes.

3.3. Estimation of greenhouse gas (GHG) emissions from the durum wheat production system

The production of durum wheat, like all plant productions, is responsible for a portion of greenhouse gas emissions. The results of the calculations and quantification gave us the following results (Table 11) where the total amount of greenhouse gas emissions from the inputs was 1,682.39 $KgCO2eq.Ha^{-1}$ distributed as follows: Chemical fertilizers, primarily nitrogen, emitted 575.34 $KgCO2eq.Ha^{-1}$ (34.19%) of the total carbon emissions, followed directly by electricity 562.56 $KgCO2eq.Ha^{-1}$ (33.43%), fuels 407.16 $KgCO2eq.Ha^{-1}$ (24.20%), human labor 133.30 $KgCO2eq.Ha^{-1}$ (7.92%), pesticides 2.89 $KgCO2eq.Ha^{-1}$ (0.17%), and machinery 1.14 $KgCO2eq.Ha^{-1}$ (0.06%). Nourani et al (2018 and 2019) find that the inputs of farmyard manure, followed by infrastructure and electricity in greenhouse vegetable production in Biskra generated the highest proportion of gas emissions with values 35%, 33% and 23%, respectively.

Table 11: Calculations of greenhouse gas emissions from durum wheat production

Input /output	Unit	GHG equivalent (KgCO2éq/unit)	Unit per hectare (unit.Ha⁻1)	GHG Emissions (KgCO2éq.Ha⁻¹)	ration (%)
Input					
Chemical fertilizer			161.69	575.34	34.19
Pesticide	Kg	5.100	0.57	2.89	0.17
Electricity	KWh	0.167	3 368.61	562.56	33.43
Machinery	h	0.071	16.0	1.14	0.06
Fuel	L	2.760	147.52	407.16	24.20
Human labor	h	0.700	190.43	133.30	7.92
Total Input				1 682.39	100

3.4. State of mechanization:

A. Degree of mechanization

The data displays different levels of mechanization for various agricultural operations, as well as the percentages of farmers using machines for these operations:

Table 12: mechanization Degree for different farm operations

Farm operation	Degree of mechanization	Percentage of farmers
Harvest	100,00%	100%
Insecticide	4,75%	5%
Fungicide	21,19%	22%
Fertilization	27,63%	29%
Weeding	70,40%	58%
Irrigation	100,00%	100%
Rolls (after sowing)	75,53%	50%
Seeder	96,30%	89%
Moulder plough	100,00%	100%
Chisel	100,00%	100%
Cover crop	100,00%	100%
Basal fertilization after plowing	67,64%	65%

The table 12 shows a high degree of mechanization for certain agricultural operations, such as harvesting, irrigation, plowing, and sowing, where 100% of farmers use machines. However, practices related to the application of phytosanitary products (insecticides, fungicides) and fertilization show lower rates of mechanization and adoption, with less than 30% of farmers using machines for these tasks. Some operations, such as the use of rollers after sowing, although largely mechanized, are only adopted by about 50% of farmers, suggesting obstacles to widespread adoption. Overall, mechanization is well advanced, but adoption remains uneven across operations.

B. Mechanization index

The provided data shows the energy inputs for three systems or crops (Semolina, Seeds, Frik), with details on the energy from machinery and human labor, and since animal energy does not exist because not all farmers use animal power. Noting that the Frik production system consumes the most energy for machinery, while the Semolina production system consumes the least. This may be due to differences in the size of the farms or the complexity of the operations that existed. Human labor represents a smaller part of the energy inputs than machinery. However, the Frik production system still requires a significant amount of human energy, while Seed production requires the least human energy. The calculations also show that the Mechanization Index for the production of Semolina, Seeds, and Frik is respectively: 71.67%, 74.94%, and 72.39%. Noticing that the three systems are relatively well mechanized, with the system producing Seeds having the highest mechanization index (74.94%). This means that the majority of operations in these systems rely on machines rather than human labor.

C. The ration of mechanization

The ration of mechanization is a crucial indicator that reflects a production system's dependence on machinery. This analysis examines the production systems of Semolina, Seeds, and Frik, by relating the energy of the machinery, the total energy, and the contribution of mechanization. With a mechanization input of 3.05%, the Frik production system shows a greater dependence on machinery, which could indicate increased efficiency and better integration of agricultural technologies. Whereas the Semolina production system, with a contribution of 2.51%, has a moderate use of machinery. This may reflect a judicious use of equipment while maintaining traditional farming practices. However, the seed multiplication shows the lowest mechanization contribution at 2.18%, suggesting an opportunity for improvement to increase machinery use and enhance efficiency.

The analysis of durum wheat production systems in Biskra reveals that the level of mechanization varies significantly depending on the type of system. The production of Frik shows the best performance in terms of mechanization input and machinery energy, which could indicate greater efficiency in resource use. On the other hand, seed multiplication, although having a high total energy consumption, shows a low integration of mechanization, which can harm its overall efficiency. According to Nourani et al, 2018 and 2019, the ration of machinery to the greenhouse production system in Biskra is only 0.8%, while the mechanization index is around 12% in the same region.

4. Conclusion :

This study aimed to evaluate the energy balance, greenhouse gas emissions, and the state of mechanization in durum wheat cultivation systems in the Ziban Biskra region. The questionnaire survey of 100 cereal farmers in the Ziban region was our main method of observation and data collection; it allowed us to build a foundation for calculating energy indicators, greenhouse gases, and mechanization indicators.

The area affected by the survey amounts to 1554.50 Ha, with an average durum wheat production of 2,880.93 Kg.Ha^{-1}. The results of the energy analysis showed that the total energy input was 41,545.36 MJ.Ha^{-1}, with the majority of the energy consumed by electricity at 12,235.83 MJ.Ha^{-1}, accounting for 29.45% of the total energy input, followed by irrigation water energy at 9,552.32 MJ.Ha^{-1}, which is 23.00%. The calculations of the energy indicators showed that the values of energy efficiency, energy productivity, specific energy, and net energy were respectively 1.15, 0.08 Kg. MJ^{-1}, 12.43 MJ. Kg^{-1}, and + 6,540.83 MJ.Ha^{-1}. The results of the greenhouse gas emissions assessment of this system showed that the total CO2 equivalent emitted from the inputs was 1,682.39 KgCO2eq.Ha^{-1}, with the largest amount of CO2 equivalent emitted by chemical fertilizer at 575.34 KgCO2eq.Ha^{-1}, or 34.19%, while nitrogen emitted 526.86 KgCO2eq.Ha^{-1}, or 31.31%. Consequently, the results obtained showed that the durum wheat production system in the Ziban region during the 2021/2022 agricultural campaign is a productive and sustainable system, meaning it produces more energy than it consumes.

Regarding the state of mechanization, the energy inputs show that the three agricultural systems analyzed are heavily dependent on machines, with a high degree of mechanization especially for soil preparation and harvesting (100%). However, there is room for improvement, particularly in the Frik production system, where reliance on human labor remains significant. It is also observed that the energy of the machinery is 1,003.5 MJ.Ha^{-1}, which is 2.41%, indicating the weak contribution of mechanization in durum wheat production.

With the aim of optimizing machine efficiency, given that machinery consumes a large portion of energy inputs, it is important to ensure that machines are used optimally (for example, through proper maintenance and better operation planning). Although the mechanization index is relatively high (74.94%), it is still possible to further reduce dependence on manual labor by integrating additional technologies such as task automation or precision agriculture.

Furthermore, investment in more efficient machines or innovative technologies could further reduce the share of human labor in the systems, particularly in the case of Frik production.

As research perspectives, further research is needed to investigate the specific energy balance and greenhouse gas emissions associated with different mechanization strategies in the Ziban region, providing valuable insights for optimizing agricultural practices and mitigating environmental impacts.

References

1. Eren, Ö., Gökdoğan, O., & Baran, M. F. (2019). Determination of Greenhouse Gas Emissions (GHG) in the Production of Different Aromatic Plants in Turkey. Türk Tarım ve Doğa Bilimleri Dergisi, 6(1), 90-96. https://doi.org/10.30910/turkjans.515360
2. Ghorbani, R., Mondani, F., Amirmoradi, S., Feizi, H., Khorramdel, S., Teimouri, M., Sanjani, S., Anvarkhah, S., & 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. https://doi.org/10.1016/j.apenergy.2010.04.028
3. H.A., K., S, A., Çakır, B., Eren, Ö., Turgut, M. M., Barut, Z., & Ozturk, H. (2011, septembre 21). Energy Balance of Wheat and Maize Crops Production in Haciali Undertaking.
4. Hadji, F. (2023). Algerian food challenges under the euro-Algerian partnership agreement wheat, potatoes, olives as a model. International Journal of Humanities and Educational Research, 5(1), 599-621. https://doi.org/10.47832/2757-5403.18.34
5. Kardoni, F., Parande, S., Jassemi, K., & Karami, S. (2013). Energy Input-output Relationship and Economical Analysis of Wheat Production in Khuzestan Province of Iran. 4, 2187-2193.
6. Khaledian, M. R., Ruelle, P., Mailhol, J. C., Delage, L., & Rosique, P. (2006). [Evolution du semis direct sur mulch au niveau du champ]. Options Méditerranéennes. Série A : Séminaires Méditerranéens (CIHEAM), 69. https://agris.fao.org/search/en/providers/122636/records/647246ede17b74d2224f57f2
7. Mani, I., Kumar, P., Panwar, J. S., & Kant, K. (2007). Variation in energy consumption in production of wheat–maize with varying altitudes in hilly regions of Himachal Pradesh, India. Energy, 32(12), 2336-2339. https://doi.org/10.1016/j.energy.2007.07.004

8. Merouche, A. (2015). Besoins en eau et maîtrise de l'irrigation d'appoint du blé dur dans la vallée du Chéliff [Thesis]. http://localhost:8080/xmlui/handle/123456789/1284
9. Ministère de l'Agriculture et du Développement Rural. (s. d.). STATISTIQUES AGRICOLES, SUPERFICIES ET PRODUCTIONS, SERIE B 2019. (Direction des Statistiques Agricoles et des Systèmes d'Information; Version 2019) [Jeu de données]. https://madr.gov.dz/wp-content/uploads/2022/04/SERIE-B-2019.pdf
10. Moghimi, M., Alasti, B. M., & Drafshi, M. A. H. (2013). Energy input-output and study on energy use efficiency for wheat production using DEA technique. https://www.semanticscholar.org/paper/Energy-input-output-and-study-on-energy-use-for-DEA-Moghimi-Alasti/293b342c71f76f6798c4d5add8ef9861fab33ea9
11. 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. https://doi.org/10.1016/j.renene.2009.09.004
12. 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. https://doi.org/10.1016/j.jssas.2014.05.001
13. Nourani, A., & Bencheikh, A. (2017a). Energy input-output analysis and mechanization status estimation for greenhouse vegetable production in Biskra province (Algeria). Agricultural Engineering International: CIGR Journal, 19(4), Article 4.
14. Nourani, A., & Bencheikh, A. (2017b, avril). Energy balance analysis and mechanization index for greenhouse vegetable production in southern of Algeria. An overview of Biskra province. NMATEH - Agricultural Engineering, 8.
15. Nourani, A., & Bencheikh, A. (2019). Energy use pattern and greenhouse gas emission in systems for greenhouse vegetable production. Agricultural Science and Technology, 11(3), 240-246. https://doi.org/10.15547/ast.2019.03.042
16. Nourani, A., & Bencheikh, A. (2020). Energy requirement optimization of greenhouse vegetable production using Data Envelopment Analysis (DEA) Method in Algeria. *Acta Technologica Agriculturae*, *23*(2), 60-66. DOI: 10.2478/ata-2020-0010
17. Nourani, A., & Bencheikh, A. (2021). Applying of DEA approach to optimize the energy required and GHG emission for greenhouse vegetable production in Algeria. *Agricultural Engineering International: CIGR Journal*, *23*(3).
18. Oukil, A., Nourani, A., Bencheikh, A., & Soltani, A. A. (2022). Using inverse data envelopment analysis to evaluate potential impact of mergers on energy use

optimization-Application in the agricultural production. *Journal of Cleaner Production*, *381*, 135199. https://doi.org/10.1016/j.jclepro.2022.135199

19. Oukil, A., Nourani, A., Soltani, A. A., Boulassel, M. R., & Bencheikh, A. (2024). Improving agricultural sustainability through farm mergers: an energy efficiency perspective. *International Journal of Agricultural Sustainability*, *22*(1), 2293598. https://doi.org/10.1080/14735903.2023.2293598
20. 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. https://doi.org/10.1016/S0961-9534(03)00080-1
21. Roger-Estrade, J., Labreuche, J., & Richard, G. (2011). Effets de l’adoption des techniques culturales sans labour (TCSL) sur l’état physique des sols : Conséquences sur la protection contre l’érosion hydrique en milieu tempéré. Cahiers Agricultures, 20(3), Article 3. https://doi.org/10.1684/agr.2011.0490
22. Samavatean, N., Rafiee, S., & Mobli, H. (2011). An Analysis of Energy Use and Estimation of a Mechanization Index of Garlic Production in Iran. Journal of Agricultural Science, 3(2), Article 2. https://doi.org/10.5539/jas.v3n2p198
23. Saunders, C., Barber, A., & Taylor, G. J. (2006, juillet 1). Food miles—Comparative energy / emissions performance of New Zealand’s agriculture industry. https://www.semanticscholar.org/paper/Food-miles-comparative-energy-emissions-performance-Saunders-Barber/f577aa8c0f4244208534664105334fdace42d12e
24. Shahin, S., Jafari, A., Hossein, M., Rafiee, S., & Karimi, M. (2008). Effect of Farm Size on Energy Ratio for Wheat Production : A Case Study from Ardabil Province of Iran. American Eurasian Journal of Agricultural and Environmental Science, 3.
25. 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. https://doi.org/10.1016/j.biosystemseng.2005.08.003
26. Singh, H., Mishra, D., & Nahar, N. M. (2002). Energy use pattern in production agriculture of a typical village in arid zone, India—part I. Energy Conversion and Management, 43(16), 2275-2286. https://doi.org/10.1016/S0196-8904(01)00161-3
27. Tipi, T., Çetin, B., & Vardar, A. (2009). An analysis of energy use and input costs for wheat production in Turkey. Journal of Food, Agriculture and Environment, 7.
28. Yadav, S. N., Chandra, R., Khura, T. K., & Chauhan, N. S. (2013). Energy input–output analysis and mechanization status for cultivation of rice and maize crops in Sikkim. Agricultural Engineering International: CIGR Journal, 15(3), Article 3.