Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.3, No.10, 2013

Energy Balance of Wheat and Barley under Moroccan Conditions

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Abstract
This study was carried out to establish the energy balance of barley and wheat, the main cultivated crops in Morocco. These crops cover about 5.3 million ha and cover 65% of the total arable area in Morocco [10]. The assessment of the energy requirements considers both direct inputs (electricity and diesel fuel) and indirect inputs (machinery, irrigation system, fertilizers, seeds and pesticides). Specific energy values were adapted from international literature and applied to national average data related to field operations. The results indicated that the total energy expenditure is 7480 MJ/ha for wheat and 3230 MJ/ha for barley. The energy efficiency in the case of wheat is 3.3 and 4.2 for barley without considering byproducts (straw, roots). The energy intensity is 4.9 MJ/kg for wheat grains and 3.7 MJ/kg for barley grains. Results revealed also that chemical fertilizers, seeds and diesel fuel consumed, respectively, 46.9 %, 18.2 % and 19.2 % of the total inputs for wheat and 20.5 %, 32.4 % and 25.5 % in the case of barley. Nitrogen represents 82% of fertilizers used; herbicides represented 87.4 % of pesticides used. Harvesting and threshing operation consumed 64.8 % and 68 %, respectively, of animal draft and manpower energy. Tillage operation consumed 46.2 % of diesel fuel.
Keywords: Wheat and barley, Energy balance, Energy intensity, Morocco

Introduction

The future of farming and agriculture hold many challenges, not least of which are continued efforts to optimize energy inputs and reduce greenhouse gas (GHG) emissions. This must to be set against the urgent and growing need to improve yields to meet the anticipated requirements to provide food, feed, fuel, chemicals and materials for the growing global population [18]. In the 1970s, agricultural systems were highly dependent on oil and other fossil fuel use. When the oil crisis started long with the associated increases in the price of crude oil, research about energy balances in agriculture was developed as along with attempts to better manage fossil fuel use [20]. Energy balance is a vital tool to evaluate the efficiency about how production systems use energy as it relates input and output energies. Morocco imports more than 95 % of its fossil energy and consumes approximately 17.2 Mtep per year [11] The agriculture sector consumes only 14 % of this energy [4], but it still presents a high potential for rational use of energy . Cereals production is one of the main agricultural sectors in Morocco. It plays a variety of roles with regard to the annual grain-sown areas of arable land, the formation of the Gross Agricultural Product, employment in rural areas and the utilization of industrial processing capacities [1]. The annual average consumption is more than 200 kg /capita, while the world average consumption is 152 kg /capita / year [8]. In spite of the importance of this sector, few studies on the energy consumption have been conducted. The objective of this study was to calculate the energy consumed and generated in the production of wheat and barley, the share of each input in the total energy consumption and the calculation of the energy indicators.

Methodology

1-Method used for the calculation of the energy balance

The International Federation of Institutes for Advanced Study (IFIAS) conducted a workshop in 1974 in Stockholm to standardize the methods for calculating balances [20]. In this study we provide an overview of the total energy use in the most important crop in Morocco: cereals. An LCA-like approach has been chosen, but the activities have been restricted to pre-farm gate activities and have excluded processing into consumer goods. The considered species were wheat and barley. Total energy covered (i) Direct energy inputs: Electricity (kWh per unit converted into MJ per unit), diesel fuel (L per unit converted into MJ per unit), consumption of fuels by the field operations and (ii) Indirect energy inputs that include energy used for manufacturing of production means, the energy used for production , transport of raw material to processing plant, packaging of final products and moving the product to the retailers to be distributed to farmers. The indirect energy associated with these activities have been estimated by multiplying physical unit of application (kg/Ha) with the parameters expressed as the volume of energy per physical unit (MJ/Kg), and resulted in estimates of the energy per hectare. Other inputs like seeds also were taken into account. The list of the energy equivalents for the categories of inputs in represented on Table 1.

Table 1: Energy Equivalents of inputs [18]

Inputs/output	Unit	Energy Equivalent (MJ/Unit)
Labor	h	1.96
Animal draft	h	4.00
Fuel	L	40.70
Lubricant	kg	45.20
Tractors	kg	91.90
Combine harvester	kg	83.50
Tools	kg	99.20
N	kg	52.62
P2O5	kg	15.55
K20	kg	12.10
Fungicides	kg-L	267.00
Herbicides	kg-L	414.00
Electricity	kW	9.60
Seeds	kg	8.00
Wheat and barley grain	kg	15.82
Surface furrow irrigation	ha/year	215 [13]
Sprinkler irrigation	ha/year	3750 [13]

The amount of inputs were calculated per hectare and then multiplied by their energy content. The total input equivalent can be calculated by adding up the energy components of all inputs in mega Joule (MJ). The energy equivalents of the inputs and output were then used to calculate the energy ratio (energy use efficiency) and energy intensity:

Energy use efficiency=Energy output (MJ/Ha)/Energy input (MJ/ha)

Energy intensity = Energy input (MJ/Ha)/Grain yield (Kg/ha)

Five agro ecologic zones were considered: Irrigated areas; Rain fed, favorable; Rain fed, intermediate; Rain fed, unfavorable; and Mountain areas.

2- Estimation of energy consumed in wheat and barley production:

The average area cultivated during the last ten years (2001-2010) was 5,160,000 Ha [10] with the largest production in the unfavorable rain-fed agro ecological zone (Table 2).

Table 2: Total area per agro ecologic zone [10]

Agro ecological area	Wheat (1,000 Ha)	Barley (1,000 Ha)	Total (1,000 Ha)
Irrigated	300	100	400
Favorable rain-fed : P*>400 mm	1,055	275	1,130
Intermediate rain-fed : 300 mm<P<400mm	420	385	805
Unfavorable rain-fed : 200mm<P<300mm	1,002	1,285	2,287
Mountain areas : 400mm<P<1000mm	194	144	338
TOTAL	**2,971**	**2,189**	**5,160**

P*: Annual rainfall

Pesticides were applied using two modes: Hand application with knapsack sprayer and mechanical application using boom sprayer. The frequency of application depended on weather conditions, on the degree of disease and weeds attack. Total use of active ingredients of pesticides per hectare varied according to type of pesticide used, ranging from 12,5 % to 48 % [2]. Fertilizers applied by farmers were: Di Ammonium Phosphate (18-46-0), 50 to 250 Kg/Ha; ammonium nitrate (33,5 %), 0 to 150 Kg/Ha; compound fertilizer NPK (14-28-14), 0 to 150 Kg/Ha; ammonium sulfate (21 %), 0 to 100 kg/ha; and urea (46 %),0 to 50 kg/ha [7]. These rates varied due to the volume of rainfall, size of farm and financial capacity of farmers. The application was either done manually, or with a fertilizer spreader. The rate of seed application depended on the species, the soil type, and the seeding technique (manual or seed drill). A common seed rate varied from 100 to 230 Kg/Ha. The main type of irrigation system used was gravity flow, sprinkler and pivot irrigation. The labor applied through mechanization depended on the number of workers and the effective field capacity for each operation. The model for the fuel consumption applied power, through the specific consumption and engine power, as adopted by Molin and Milan (2002). The fuel consumption varied according to farming system used (Table 3)

Table3:Fuel consumption per farming systems

Operation	**Mechanized Farming (MF)**			**Traditional farming (TF)**	
	MF 1	MF 2	MF 3	TF1	TF2
Tillage operation	Stubble plow or Mold board plow or Chisel+ 1 to 2 passes disc harrow	2 to 3 passes Disc harrow	1 pass Disc harrow	Draught animal	
Seeding	Seeder	Manual			
Fertilizer application	Spreader	Manual			
Pesticide application	Boom Sprayer	Manual			
Harvesting and threshing	Combine harvester	Combine harvester	Manual harvesting thresher		Manual harvesting
Transport	Trailer			Draught animal	
Total Diesel consumption (L/ha)	55 to 66	35.5	20	5	-

The machinery physical depreciation (Table 4) was based on the useful life and the mass of the machinery, and on specific capacity they perform in the mechanized operation; it is possible to determine the machinery depreciation by this equation:

EDM= (E mach *M)/(UL*FC)

Where EDM=energy on machinery depreciation (MJ/Ha), M:Machinery mass (Kg), E :mach:energy content of machinery (MJ/kg), and UL :Machinery use life (h),FC: field capacity

The physical depreciation does not mean that equipment loses weight, but it means that after its useful life, the same amount of mass will be required to build a new one in order to replace it

Table 4:: Energy consumed through machinery depreciation

Machines/tools	Mass Kg	Energy Equivalent	Machinery usefull life	Field capacity Ha/H	Mj/H or /Ha
Tractor 51.4 Kw	2400	95.67	10000	1	23.0
Combine harvester 84.5Kw	6000	83.5	12000	1	41.8
Threasher	1500	99.0	2000	1	74.3
Disc plough 0.9 m	420	99.2	2000	0.3	69.4
Disc Harrow 2.30 m	800	99.2	2000	1.2	33.1
Stubble plow 1.80 m	1430	99.2	2000	0.75	94.6
Chizel plow 1.20 m	400	99.2	2000	0.9	22.0
Cultivator 11 elements	380	99.2	2000	2.1	9.0
Drill 3.00 m	760	99.2	1500	1.5	33.5
Spreader 12 m	90	99.2	1200	3.5	2.1
Boom sprayer 12 m	500	99.2	1200	4	10,3
Trailer 5 T	1750	99.2	2000	1.2	72.3
Baler	1500	99.2	2000	1.0	74.4
Knapsack sprayer	4	99.2	1500	0.25	1.1

Irrigation area represents 7.8 % of the total area sown in wheat and barley. Two main systems were used: Surface furrow irrigation (80%) of irrigated area and sprinkler irrigation(20%). Draft horse farming were used in hilly areas in tillage, threshing and transport operations.

Results

The amount of energy consumed in cereal production was $29x10^3$ Tera Joule, and 75.9 % of this energy is

Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
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consumed in wheat production (Table 5).

Table 5 : Total Energy consumed

Input (energy form)	Energy consumption in Tera Joule		
	Wheat	Barley	Total
Fertilizers	10,417	1,448.3	11,865.3
Pesticides	547.6	83.3	630.9
Seeds	4,054.7	2,288.6	6,343.3
Diesel Fuel and lubricant	4,226.3	1,800.2	6,026.5
Machinery depreciation	1,028	478.5	1,506.5
Depreciation of Irrigation systems	1,421.4	299.0	1,720.4
Manpower	249.6	307.1	556.7
Animal draught	280.9	360.5	641.4
TOTAL	22,225.6	7,065.5	29,291.1

The results revealed that fuel and lubricant, seeds and fertilizers consume 84.1 % and 78.4 % of the total inputs respectivly for wheat and barley (Figure1 and Figure 2).

Figure 1 :Share of the total energy used :Wheat

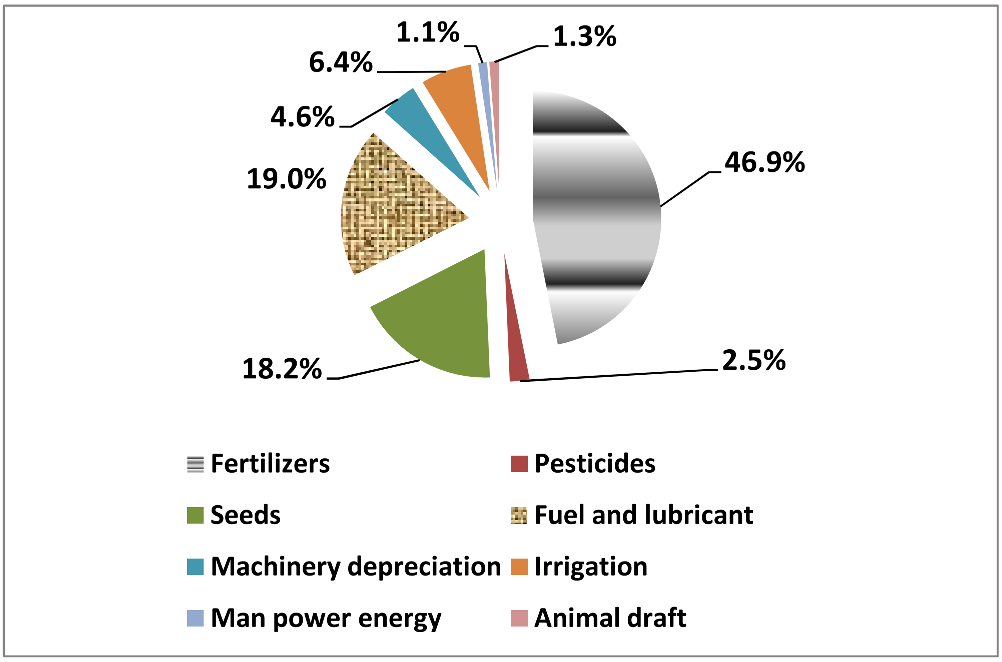
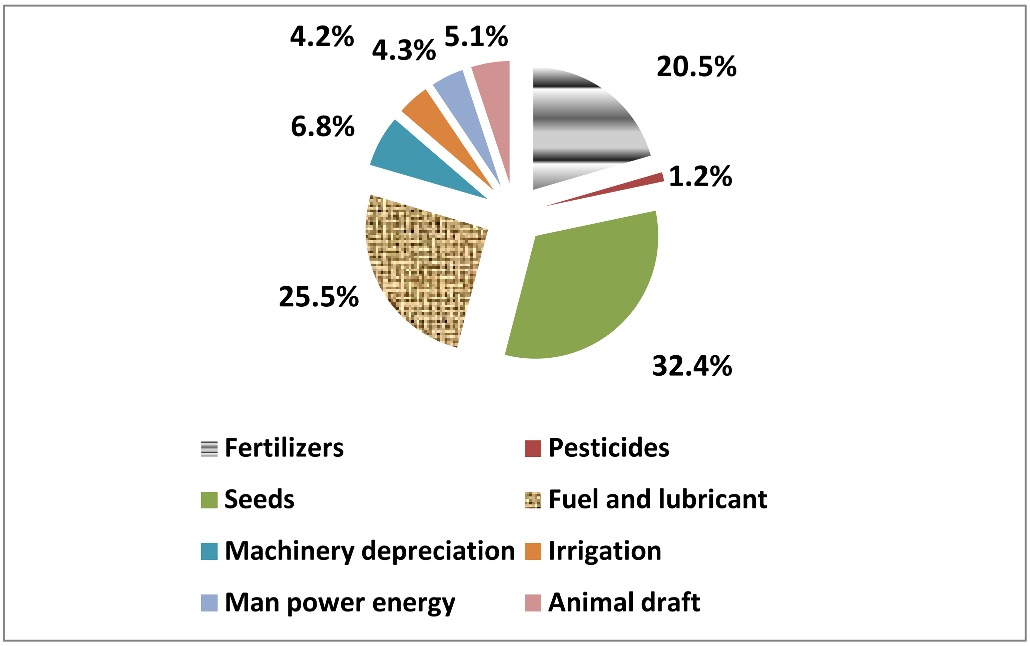


Figure 2: Share of the total energy used: Barley



Among individual input , nitrogen consumed 81.9 and 82.9 % of fertilizers respectivley for wheat and barley. Herbicides consumed 87% to 89.6 % of pecticides. Harvesing and threashing consumed 65.6 % in case of wheat and 70 % in case of barley of manpower (Figure 3). Tillage operation consume 45.1 to 48.7 % of fuel energy (Figure 4).

Figure 3:Share in % of labor use

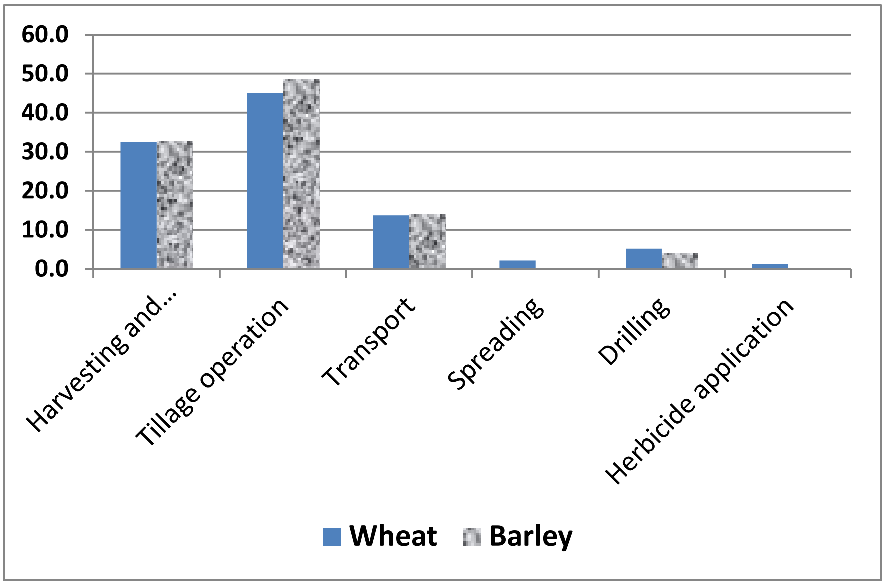
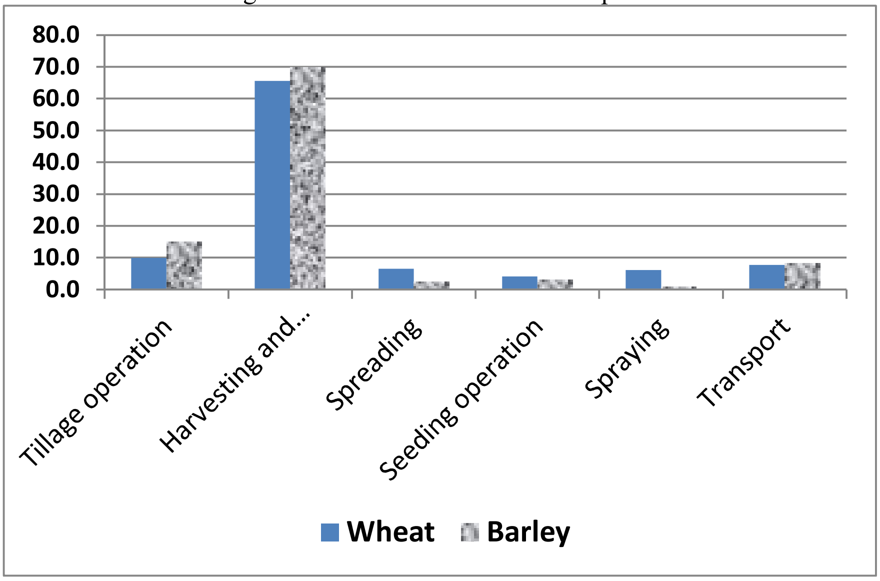


Figure 4:Share in % of fuel consumption



The average energy input for cereals produced in Morocco were calculated to be 7480 MJ/ha for wheat and 3230 MJ/ha for barley (Table 6). The energy use efficiency was 3.3 in wheat and 4.2 in barley. The energy needed to produce one kilogram of barley was 3.7 MJ for barley and 4.9 MJ for wheat.

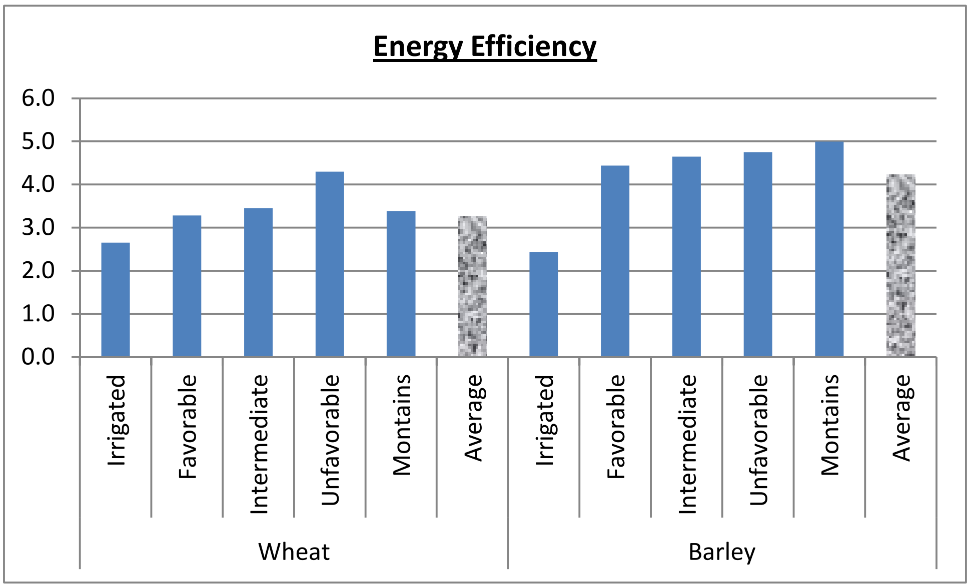
Table 6: Energy used fpr production of wheat and barley in different agro ecologic sones expressed as megaJoules per hectare (MJ/ha)

Zone	Irrigated	Favorable Rainfed	Intermediate Rainfed	Unfavorable rainfed	Montains areas	Average
Wheat	20496	8929	6442	2947	5143	7481
Barley	13990	4713	3605	2001	2854	3228

Discussion and conclusion

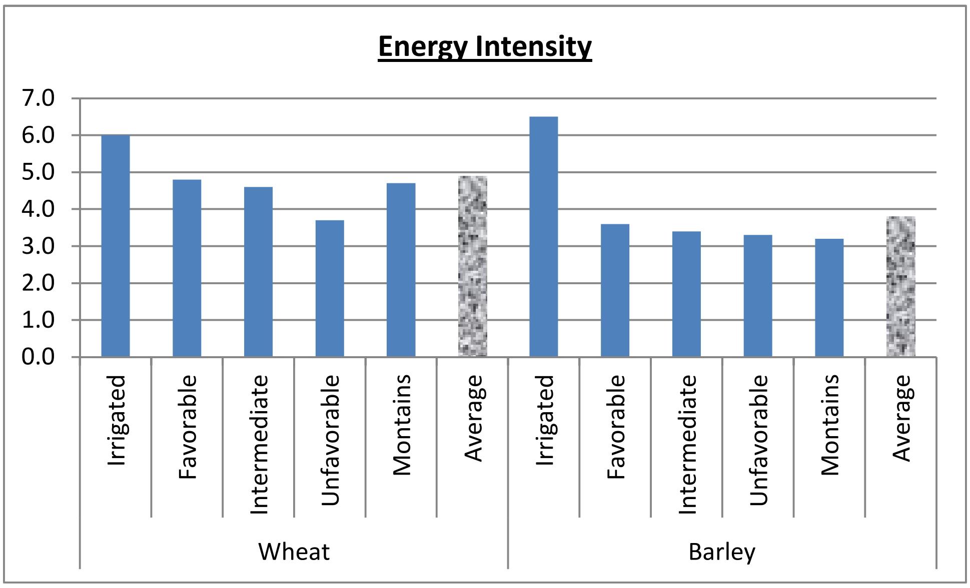
Similar results were reported that the energy input of chemical fertilizers has the biggest share of the total energy input in rain-fed wheat production. The energy efficiency varies widely according to the species and the agro ecological area. The efficiency was slightly higher for barley because it is used by farmers as animal feeding and thus receives less inputs. The average energy consumption (MJ/ha) for wheat in Morocco was low according to the research findings, India 8496-21032, Italy 23990, Turkey 18680 [5]. The energy efficiency was relatively lower for wheat (3.27) in comparison to barley (4.23). This ratio (Figure 6) was similar compared to farms in New Zealand (Barber ,2004), Turkey (Canakci et al,2005), India (Singh et al,2002) and Pakistan (Khan and Singh,1996; Khan et al 2007), where it was 2.9, 2.8, 3.2, 2.5 and 3.46, respectively [9]. The energy efficiency was calculated to be Chile 2.74-4.69, Antalya Turkey 2.8 [5], Kenya 3.31,USA 2.57 [6], in France, this ratio is 6.55, higher in Australia 9.21 for wheat and 8.21 for barley, low in some localities Western Macedonia 1.45 [14].

Figure 6: Energy efficiency per specie and per Agro-ecological zone



We consider that the energy system of wheat production in Morocco is low energy input and low energy output. The developed countries high energy input and high energy output this explain why the energy efficiency is similar with these countries. An effort must be made by farmers in order to improve the energy efficiency. As for the intensification, wheat is considered to be the main source of income to farmers, while barley is used for animal feeding. Average energy intensity in case of Morocco is 4.9 for wheat (Figure 7) , it was calculated in Greece to be between 5.2 and 6.45 MJ/kg, 3.5 to 4.5 in Italy (Pellizzi).

Figure 7: Energy intensity in Mj/kg per specie and Agro-ecological zone



Theobald Olivier reported for Europe 2.4 to 11, for USA 2.9 to 32, for Canada, 1.1 to 3.9, and for for Argentina, 2.4 to 3 [18]. Turkey had a energy intensity of 5,88 [5]. The low consumptions in fuels and the high rate of use of manpower means that the cereals are under-mechanized compared with the developed countries where the labor rate is between 5 to 10 hours and the fuel consumption per hectare 80 L / ha in United States and Germany [13]. Draft animals and manpower are more common in the case of barley because it is generally cultivated in mountainous localities that are difficult to access.

This study was an overview of the use of energy in cereals in Morocco, the energy varied widely according to the crop and the agro ecological zones. These results showed that the most energy consuming in wheat production among agro-ecological zones is favorable rain-fed area, so an advanced survey is recommended at the level of farms located in these zones where the degree of intensification is also so high. This study will allow us to analyze deeply the degree of the use of inputs, defines and analyses the sources where economy of energy is possible.

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