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Evaluation of Fuel Consumption in Agricultural Field Operations in Saudi Arabia

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Abstract: The present study has been conducted to evaluate the fuel consumption of the farm machinery in Saudi Arabia to attain the optimum use of fuel and to reduce the field operating cost. Eight areas have been selected carefully for their agricultural importance and geographical representation. The theoretical fuel consumption was calculated according to the need of implement of the agricultural operations. The calculation was based on the draft and power requirements for the operations of the main tillage. The actual fuel consumption was estimated based on the available powers. The ratio of the actual to the calculated fuel consumption was considered as criteria of the optimal use of fuel in different agricultural operations. Results revealed that the majority of the farms in Saudi Arabia consume fuel more than the required for performing the agricultural operations. The fuel consumption indicator showed that about 40% of the fuel was lost. For a medium soil texture (firm soil), the actual fuel consumption was higher by 8.2% than the calculated fuel consumption. The indicator of fuel consumption for palms, citrus, fodder crops and wheat were high, while it was low in case of potato crop. An average fuel consumption indicator of 0.13 and 3.43 l/h.ha, was obtained for agricultural companies and special farms respectively.

Key words: Fuel Consumption · Agricultural Operations · Saudi Arabia Farms

INTRODUCTION

Using the agricultural machinery and engineering applications in the agricultural sector have positive impact on all aspects of production. This is because the engineering applications play the most important role to increase the productively of crops. The engineering applications make the agricultural operations more quickly and neatly and increase the operations performance. Thus it provides conditions more suitable for the production of crop. Therefore, the agricultural machinery and equipment have been applied on a large scale in the Saudi Arabia. This moved agriculture areas from small holdings to vast tractors owned by companies and agricultural institutions [1].

In the last decade, the price of diesel fuel increased to be priced at 0.09 $/l, this nearly equals to three times of the previous rate. The large size of machinery and tractors (i.e. output power) in Saudi farms, make the cost of fuel consumption (operating costs) are very high. The tillage operations for several times to prepare an appropriate seedbed are an essential component of fuel consumption for producing crops [2].

Large number of farms in Saudi Arabia use equipments and machinery much more than the actual needs therefore, the fuel consumption as well as the overall cost increases. The actual amount of fuel consumed per unit area of farm in the Kingdom was from 2 to 10 times the optimal amount [3,4]. This was mainly due to the lack of experience and information in this area.

Al-Suhaibani *et al.* [5] evaluated the use of energy in agriculture of the field operations in Saudi Arabia farms. They found that there was a relationship between the actual power and the cultivated area and it was a direct correlation up to300 ha.

Safa *et al.* [6] determined fuel consumption in wheat production in New Zealand (Canterbury area). Their analysis was based on the operational fuel consumption

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by field machinery. Total fuel consumption for wheat production was estimated to be 65.3 l/ha on average. The average of fuel consumption for tillage and harvesting were 29.6 and 18 l/ha more than in other operations.

Hatirli *et al.* [7] recommenced that increasing the use of fuel may cause some environmental problems such as increasing the heat of the universe and the emissions of carbon dioxide.

Frisby and Summers [8] estimated the fuel needed to run some agricultural machinery in three types of soil. They found that the amount of fuel consumed in the tillage operations strongly depends on the type of soil. The average fuel consumption was higher in clay soil followed by loam soil and the lowest was in sandy soil.

Butterwoth and Nix [9] showed that the energy required to operate a grain drill in a clay loam and clay soils were 22 and 34 MJ/ha, respectively. The value of the energy required to operate a chisel plow, a rotary plow and a rotary plow with grain drill in a clay soil were about 135, 154 and 193 MJ/ha, respectively. Schrock *et al.* [10] reported that the fuel requirements ranged from 41.3 L/ha for sorghum to 50.8 L/ha for corn.

Al-Janobi and Wahby [11] studied the importance of rationalizing energy use in agricultural operations. They implemented three type of tillage (chisel plow, moldboard plow and disk harrow). They found that there are differences in the fuel consumption among them. The chisel plow showed the lowest fuel consumption compared with the other tillage implemented.

Al-Suhaibani and Wahby [12] estimated the fuel requirement for field operations of wheat production in Saudi Arabia. They found that the amount of fuel consumption per unit area were 2-10 time higher than that reported in other studies.

Al-Suhaibani [13] studies the utilization of farm power and machinery in wheat farms in Saudi Arabia. He found that the mechanization provision of tractor power and machine size were very low compared to other studies. He suggested that to overcome the poor utilization of tractors and machines, the farm area should be expanded or establish service station for mechanization. Also, it is necessary to establish a data bank that includes information needed for farm machinery selection, power and suitable models.

The previous survey showed the importance of undertaking a comprehensive study on fuel consumption in Saudi farms. Therefore the objective of the present study was to evaluate the amount of fuel needed to run agricultural equipment for different agricultural operations and compare with the actual quantities to demonstrate optimal use of fuel.

MATERIALS AND METHODS

To evaluate the fuel consumption in the agricultural operations in Saudi Arabia farms, data was collected from 191 farms in the following locations: Qassim, Madinah, Tabuk, Hail, Jouf, Riyadh, Abha and Jizan. These locations were selected according to their importance to agriculture, geographical representation and the availability of the data. In addition, data from eight agricultural companies, which had accurate records of fuel consumption, were collected.

The collected data were the farm area, type of crop, number of tractors, types and numbers of agricultural machinery,

The fuel consumption was estimated by recording the number of filing the file tank per year and the tank capacity. Thus, the actual fuel consumption (AFC) l/hr for whole operations (tractors, agricultural machinery, irrigation equipment, farm and other uses) was estimated according to the following equation:

$$AFC = \frac{TC \times NFT}{T}, \quad l/h \tag{1}$$

Whereas:

TC = capacity of the tank, l;
NFT = Number of filled times per year and
T = Total operating hours per year, h.

The theoretical fuel consumption (TFC), l/hr was calculated according to the following steps:

Measuring the Draft Force and Rolling Resistance: Measuring the draft force was obtained by recording the measured draught force by dynamometer between two tractors (pull tractor in the front and mounting plow tractor in the rear). Rolling resistance is the force required to pull the tractor when the plow in the lifted position. It is proportional to equipment weight [14]. Estimating the rolling resistance of the tractor is necessary to calculate the net plowing draft force required for the plows at the operating speeds. The rolling resistance of a tractor equipped with mounted plow was determined at no load, while the plowing draft force was determined during plowing operation. More readings were recorded by the measuring system during plowing at different speeds and the mean values were calculated. The net draft force (F), kN was calculated as follows:

$$F = FF\text{-}RR \tag{2}$$

whereas:
DF = Plowing draft force, kN and
RR = Rolling resistance force, kN.

Power Consumption: The power consumed by the plow (P) in kW was calculated as follows:

$$P = \frac{F \times V}{3.6} \quad (3)$$

whereas:
V = Plowing speed, km/h and
F = Net plowing draught force, kN.

The theoretical Fuel consumption (TFC), l/hr was calculated according to Barger *et al.* [15].

$$TFC = \frac{P \times (3600 \times 75 \times 1.36)}{\rho_f \times L.C.V. \times 427 \times \eta_{th} \times \eta_m} \quad (4)$$

whereas:
P = Power requirements, kW;
ρf = The density of the fuel, 0.85 kg/l;
L.C.V = Lower calorific value of fuel 10000 kcal/kg;
427 = Thermo-mechanical equivalent, kg.m/kcal;
η_{th} = Thermal efficiency of engine, 35% for diesel engine and
η_m = Mechanical efficiency of engine, 80% for diesel engine.

The fuel consumption indicator, (FCI) l/h.ha was calculated by following equation:

$$FCI, (l/h.\ ha) = \frac{\text{The total fuel consumed, (l/h.)}}{\text{Farm area, (ha)}} \quad (5)$$

RESULTS AND DISCUSSION

Fuel Consumption in Private Farms: The effect of number of tractors, different region, soil type and crop type on the rate of fuel consumption and indicator of fuel consumption in private farms were illustrated as follow:

Number of Tractor: Table 1 shows the relationship between the mean number of tractors for each region and the average actual fuel consumption (AFC) l/hr. The lowest number of the tractors was 1.0 tractor in Medina region and the largest mean number of tractors was 2.9 tractors in Al Jawf, as well as the lowest average fuel consumption of tractor. This results may be due to the used tractors in Al Jawf had less power than that of other regions. Also, data show that the highest values of fuel consumption were recorded with Hail region.

Different Region: Results in Table 2 showed that the average ratio between the actual and calculated fuel consumption was 1.40. This means that the average increase of was 40%. This is undoubtedly a significant increase and in turns affects agricultural production.

From the recorded data, it was found that the theoretical average of fuel consumption indicator for all farms was 2.89 l/h.ha, where it was 0.34 to 17.28 l/h.ha in Al Jawf and Abha farms, respectively. This was due to the increase of average holding area in Al Jawf (50.3 ha), while it decreased in Abha to (1.3 ha).

Soil Type: The indicator of fuel consumption as affected by soil type was illustrated in Fig. 1. Three soil types included in this study (heavy, Medium and light). The recorded data indicated that the medium soil consumed fuel 82% more than theoretical fuel, compared with 30 and 20% for light and heavy soils, respectively.

Crop Type: The effect of crop type on fuel consumption indicator was plotted in Fig. 2. It is clear that the palm, citrus, fodders and wheat crops have a greater values of fuel consumption indicator than other crops. The increase of fuel consumption indicator for these crops was attributed to multiple agricultural operations in addition to increase the agricultural tractors power exists more than required. Also, results revealed that the fuel consumption indicator for potato crop was lower than other crop. This was attributed to increase the cultivated area in addition to potatoes grown twice a year.

Fuel Consumption in Agricultural Companies: The cultivated area (ha), total quantity of fuel consumed (l/hr) and indicator of fuel consumption (l/h.ha) for some agricultural companies were listed in Table3. It was clear that the mean indicator of fuel consumption of agricultural companies was 0.13 l/h.ha comparing to 3.43 l/h.ha for private farms.

Figure 3 shows the indicator of fuel consumption for different crops in agricultural companies. It can be seen that the highest FCI value recorded with fodder crops, while the lowest value recoded with vegetables. Also, it can be observed that the indicator of fuel consumption were found to be 0.79 and 1.76 l/h.ha in agricultural companies comparing to 7.3 and 3.23 l/h.ha in private farms for wheat and potato crops, respectively.

Table 1: The effect of the mean number of tractors in each region on the ratio of actual to theoretical fuel consumption

Region	Mean No. of tractors per region	Average AFC of the region (l/h)	Average AFC of the tractor (l/h)
Hail	1.96	57.37	29.27
Abha	1.20	26.96	22.47
Madina	1.00	19.25	19.25
Tabuk	1.60	31.98	19.99
Dawaser	1.30	31.34	24.11
Qassim,	1.60	34.72	21.70
Riyadh	1.60	40.61	25.38
Al Jawf	2.90	31.60	10.90
Jizan	1.10	21.35	19.41
Kingdom average	1.50	32.80	21.39

Table 2: The effect of the different regions of study on the ratio of indicator of average the actual fuel consumption on the theoretical

Region	No. of Farms	Average cultivated area ha	Indicator the AFC l/h.ha	Indicator the theoretical fuel consumption l/h.ha	Ratio indicator of average fuel actual consumption to the theoretical
Hail	25	67.7	0.85	0.47	1.80
Abha	10	1.3	20.74	17.28	1.20
Madina	10	4.8	4.01	4.46	0.90
Tabuk	17	55.4	0.58	0.48	1.20
Dawaser	25	43.3	0.73	0.56	1.30
Qassim,	22	63.5	0.55	0.61	0.90
Riyadh	37	62.2	0.66	0.41	1.60
Al Jawf	29	77.8	0.41	0.34	1.20
Jizan	16	9	2.38	1.40	1.70
Kingdom average	191	51.7	4.05	2.89	1.40

Table 3: Average fuel consumption indicator for some agricultural companies

Company number	Agricultural area (ha)	The total of fuel consumption (l/h)	Indication of fuel consumption (l/h.ha)
1	3700	538.04	0.15
2	8917	1889.02	0.21
3	7200	328.26	0.05
4	13560	2899.02	0.21
5	5000	1419.40	0.28
6	13120	1025.35	0.08
7	18025	657.44	0.04
8	14000	853.07	0.06
9	10200	1087.53	0.11
Kingdom average	10413.56	1187.53	0.13

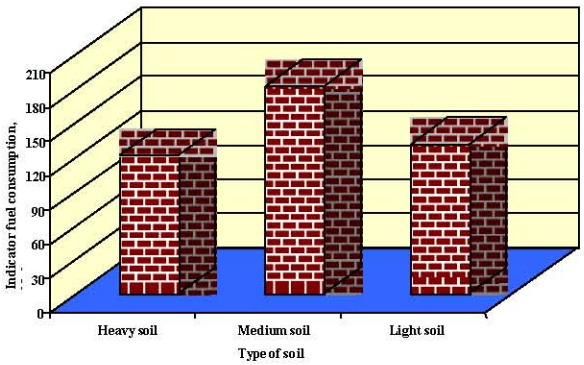

Fig. 1: Effect of soil type on indicator average fuel consumption ratio, %.

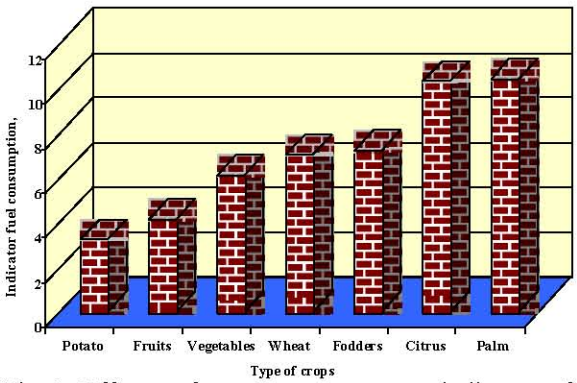

Fig. 2: Effect of crops type on indicator fuel consumption, l/h.ha.

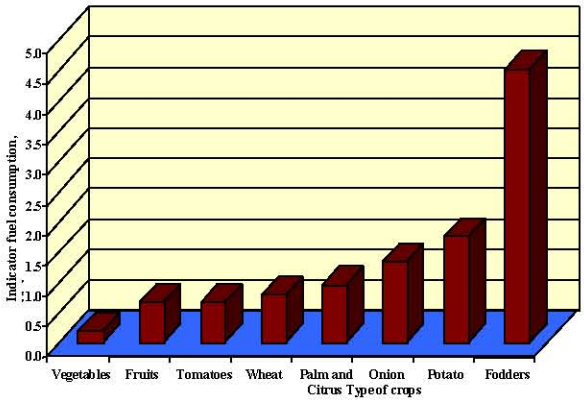

Fig. 3: Effect of crops type on indicator fuel consumption (l/h.ha) for agricultural companies.

The decrease of fuel consumption indicator in agricultural companies was attributed to increase cultivated area in agricultural companies and optimal use of available power in addition to the use of suitable operational programs for tractors and agricultural equipment and good management of agricultural inputs.

CONCLUSION

From the above Results, the Specific Conclusions Include the Following:

- There is a 40% loss in the AFC for the farms included in the study.
- The medium textures soil (Firm soil) consumed 82% fuel more than the theoretical fuel quantities.
- High values of FCI were recorded for palms, citrus, fodder crops and wheat. However, it decreased for the potato crop.
- The FCI of 0.13 and 3.43 l/h.ha were found for agricultural companies and private farms, respectively in the Saudi Arabia.

Further investigation is needed; particularly for farms that have accurate records (log-book) of the tractors and farm equipment to find how to reduce excess fuel consumption. Also, create Agricultural Engineering stations to provide agricultural operations service in order to minimize the fuel consumption and optimal use of power.

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