Field Efficiency and its Use for Energy Coefficient Determination

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Abstract: Field efficiency is the most used factor in determining the effective field capacity but yet not known for Iran. This figure for different machines and field conditions are tabulated in ASBAE standards and cited in many publications as a range for different speeds but; they may not hold true for different conditions in different areas. The field efficiency is also needed for converting fuel used in field operation from l/h into l/ha and many more of the kind. Field experiments were run to determine the field efficiency (FE) by measuring wasted time as well as running time for a moldboard plough, chisel packer, tandem disk, mechanical row planter and pneumatic row planter. The energy coefficient for these implements were also obtained and compared. A mean FE of 73.16%, 75.33, 73.5, 68.16, 73.8 and 64.4 and energy coefficient of 26.36, 14.06, 12.19, 6.64, 4.96 and 7.10 l/ha were obtained for moldboard plough, chisel packer, chisel, tandem disk, mechanical planter and pneumatic planter respectively.
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1. Introduction

Field efficiency is the most used factor in determining the effective field capacity but yet not known for Iran. This figure for different machines and field conditions are tabulated in ASAE standards and cited in many publications as a range for different speeds but; they may not hold true for different conditions in different areas. Measurements or estimates of machine field capacities are used to schedule field operations, power units, and labour, and to estimate machine operating costs. Hunt (1995) states that 10 items are involved in time efficiency out of which only 6 are included in field efficiency. Time efficiency is a percentage reporting the ratio of the time a machine is effectively operating to the total time the machine is committed to the operation. Field efficiency within the range of 88-74, 90-77, 90-75 and 78-55% are given for mouldboard plough, disc harrow, chisel plough and row crop planter respectively. ASAE standard D497.4 FEB03 lists a range of field efficiency for many machines. For mouldboard plough, tandem disk harrow, roller packer, chisel plough and row crop planter they are all within the range of 70-90% with typical values of 85, 80, 85, 85 and 65% respectively. Al-Hashem (2000) measured field efficiency to be 20.6%, 18.0% and 23.6% for disc plough, tooth harrow and levelling implement, respectively. These efficiencies are much lower than that recommended by ASAE. Moreover, efficiencies greatly varied among the farms for these implements for each specific operation. Hanna (2002) has given values of 85, 85, 83 and 70 percent for plough, chisel plough, tandem disk and air seeders respectively. He also mentioned that the FE can be taken from the table in his publication or estimated using equation (1) if you have a representative value of EFC (Effective Field Capacity). FE(%)=EFC/TFCx100 (1) where FE is the abbreviation for field efficiency, EFC for effective field capacity and TFC for theoretical field capacity. Helsel et al (2011) stated that machine maintenance and repair affect field efficiency – equipment that is well-maintained and in good condition operates most efficiently. To reduce turning time, farmers should strive to make fields large, long, and narrow by eliminating fence rows, ditches, or other barriers. Larger implements, if matched to tractor size, can be more field efficient because bigger implements cover larger areas and require a smaller number of turns. Al Hamed (2005) measured field efficiency, effective field capacity, fuel consumption per unit area, and specific fuel energy were estimated during tillage operation in sandy loam soil for three chisel ploughs with different shank shapes. For all the three ploughs, the results showed an inverse relationship between field efficiency and forward speed, and field efficiency values were close at each speed of the four forward speeds. Abubakar et al (2009) assessed the effects of soil physico-mechanical properties on performance efficiencies of ox-drawn mouldboard plough was conducted with the results that FE was highest (0.133 ha/hr) in Sabon-gari and lowest (0.112 ha/hr) in FDF (Futy Demonstration Farm) at the same soil M.C. (25%). Lowest time losses of 13 and 14 minutes was at 10 and 25% soil M.C.in Sabon-gari with relatively lower (1.35 Mgm^{-3}) soil compactions. Grisso et al (2001) compared the fields that are relatively flat with straight rows with contoured fields with slopes up to 3 to 5%. Field efficiency, travel speeds, and unproductive time lapses were compared. When contour patterns were compared with the straight rows, field efficiency dropped on the contours by 10 and 20% for planting and harvesting, respectively. Bochtis et al (2010) monitored and analyzed two machinery operations in two different fields. The results show that the implementation of the CTF (Controlled Traffic Farming) system rather than the UCTF (Uncontrolled Traffic Farming) system significantly increases the in-field transport distance traveled by the application unit. The reduction in-field efficiency, in terms of transport distance, ranged from 4.68% to 7.41%. Peg Zenk (2003) proved that GPS systems can provide all the data you need to monitor equipment efficiency. “What improves field efficiency numbers is long, straight rows, and we've always known that,” Taylor says. “But now we can quantify it.” He found that increasing planter size will make an operation more productive but less efficient. A grower can do more work with two 8-row planters than one 16-row model, he notes. Ehsani (2010) stated that in the past, calculating factors such as field efficiency was very difficult, time consuming, and required someone with a stopwatch on-site during operation. Now, GPS can be used to obtain this information much faster and simpler. Khan et al (2010) computed direct energy inputs for wheat, rice and barley crops contain human, pumping, tractor or other self propelled machinery and indirect energy sources are seed, fertilizer and plant protection agro-chemical. Maximum energy consumption was on the farms of rice (6699 kWh ha^{-1}) compared to other two crops (wheat 3028 and barley 2175 kWh ha^{-1}). Behroozi Lar et al (2009) obtained the energy coefficient for growing irrigated wheat in four provinces of Iran and concluded that these provinces used 24.10 to 38.98 $GJha^{-1}$ to produce one hectare of irrigated wheat compared to 23.67 $GJha^{-1}$ predicted for the worst case. Singh (2002) obtained 15.29 $GJha^{-1}$ for producing irrigated wheat In dry and hot places in India. El Hussein and Van Ouwekerk (2005) obtained a value of 13.96 $GJha^{-1}$ for wheat production in Morocco. Slotz (2000) extracted data for conventional wheat production for three varieties of wheat with means equal to 18.3, 17.2, 16.5 and 17.33 $GJha^{-1}$ and 3.10 $GJha^{-1}$. Sidhu (2004) obtained 19.58 $GJha^{-1}$ for producing wheat in one of the provinces of India.

2. Material and Methods

Eighteen plots of 67×10 meter were randomly adopted to implement three tillage operations in six replication with randomized completely block design. The tillage treatments were moldboard plough, chisel packer and chisel. Disking operation was performed on each plot after plowing. Two methods of planting that is mechanical row crop planter and Pneumatic row crop planter were used for seeding. Time spent and fuel consumption for tillage operations and planting as well time and fuel consumption for turning at the head lands were recorded. Field efficiency was calculated using the equation (2).

$$FE = \frac{PT}{PT + TT} \qquad (2)$$

Where PT is productive time, TT = turning time. Other involved wasted times such as repair and maintenance, loading and etc. were not considered because no such operations were performed. Field capacity was then calculated from equation (3).

$$C = \frac{vwe}{10} \qquad (3)$$

Where v is speed in km/h, w = implement working width in meter and e the field efficiency in decimals.

The energy coefficient in l/ha fuel used was determined by dividing the measured fuel use in l/h by the field capacity. The fuel used for machine operation was calculated from equation (4) and machine drawbar power from equation (5) below,

$$l/h = 4.93 + 0.1997 \times 0.75 \times P_{dbm} \qquad (4)$$

$$P_{dbm} = \frac{Fv}{3.6} \qquad (5)$$

Where P_{dbm} was requirement power for machine operation in kW, F = draft force of the implement in kN. The equivalent draw bar power need for tractor movement calculated form equation (6).

$$p_{dbt} = \frac{fmgv}{3600(1 - S\%)} \qquad (6)$$

f was the rolling coefficient against the tractor wheels, m the tractor mass in kg, g the gravitational force= 9.81, v the speed and S% the wheel slip in decimals. The P_{dbt} was added to P_{dbm} in equation (5) prior to calculating the l/h.

3. Results and Discussion

Mean data collected and calculations is shown in table 1. The field efficiency (FE) for ploughs and the mechanical planter with were not significant at 1% probability level. Therefore a mean value of 74% may be used for all and every one of these implements. FE for disking with a value of

0.68 and for pneumatic planter of value 0.63 were significantly different at 1% level which also were differently significant from FE for ploughs. Table 2 shows a comparison of the results with that from different cited references: ASAE, Hunt (1995) and Hanna (2002). The experimental FE for moldboard and chisel plough was about equal to the minimum value given by Hunt but much lower than the typical value of the ASAE and Hanna (2002). For the tandem disk harrow and roller packer, the experimental value was about 15% lower than the one given by ASAE. The experimental row crop planter FE was close to the highest of the Hunt (1995) and about 15% higher than the one given by ASAE. The bar graph for this comparison is shown in figure 1. A bar graph of energy coefficient versus speed for different machines is shown in figure 2. Energy coefficients (EC) for machine operations are also shown in table1. For comparison, the EC cited from Anonymous (2007), Anonymous (2007), Cromwell (1995), Anonymous (2001), Griffth et al (2005) and Molenhuis (2001) is shown in table 3. It seems that the experimental EC for moldboard was at least 1.5 times the maximum given in table 3. This could be due to including the tractor fuel use in experimental calculations while this fuel might have not been accounted for in the figures of table 3. No EC for chisel packer was found in the mentioned literatures. The experimental EC for this machine from table 1, was 14.06 l/ha. This implement needs more power and therefore more fuel use than a chisel alone. Regarding this matter, the EC for chisel packer obtained in the experiment compares well. The EC for other machines seems to be very well adapted comparing to the international figures (Anonymous, 2007; Anonymous, 2007; Cromwell; 1995; Anonymous, 2001; Griffth et al, 2005 and Molenhuis, 2001) in table 3 specially when considering the relatively lower experimental field efficiency in Iran. Significant differences were observed at 1% level between all the machines except for the two implements that is Chisel packer and Chisel ploug.

Table1. Mean data collected and calculations

	Moldboard plough	Chisel packer	chisel	Disk	Mechanical planter	Pneumatic planter
Plowing/Planting time(h/ha)	1.97	1.09	0.85	0.49	0.74	0.76
Turning time (h/ha)	0.69	0.35	0.29	0.22	0.25	0.40
Field efficiency*	73.16^{a}	75.33^{a}	73.50^{a}	68.16^{b}	73.80^{a}	64.40^{c}
Slippage (%)	23.0	12.0	7.7	19.0	14.28	18.81
Speed across field (km/h)	4.57	4.43	5.97	8.09	8.07	7.85
Energy coefficient for plowing/planting (l/ha)*	26.36^{a}	14.06^{b}	12.19^{b}	6.64^{c}	4.96^{d}	7.10^{c}
Energy coefficient for turning (l/ha)	5.41	1.90	2.07	1.04	1.20	1.93
Machine width(m)	1.2	2	2	2.5	1.8	1.8

* Means in rows with different letter are significant at 1% probability level.

Table 2. Comparison between the experimental and the cited FE.

References	Experimental	ASAE	Hunt	Hanna
Moldboard plough	74	85	88-74	85
Chisel plough	74	85	90-75	85
Tandem disk	68	80	90-77	83
Roller packer	74	85	-	-
Row crop planter	74	65	78-55	-
Pneumatic R C planter	63	-	-	70

Table 3. Energy coefficient for machine operations cited from published literatures, l/ha.

References	Moldboard plough	Chisel plough	Tandem disk	Row crop planter	Air seeder
Anonymous (2007)	18	-	12	-	-
Cromwell et al (1995)	17.5	-	4.4	-	-
Cromwell et al (1995)	13.5	-	4.8	-	-
Anonymous (2001)	16.5	10.7	6.8	-	6.3
Griffith et al (2005)	18.0	12.0	-	-	-
Molenhuis (2001)	11.30	5.25	3.75	3.0	-
Anonymous (2007)	16.4	12.6	6.8	4.8	-

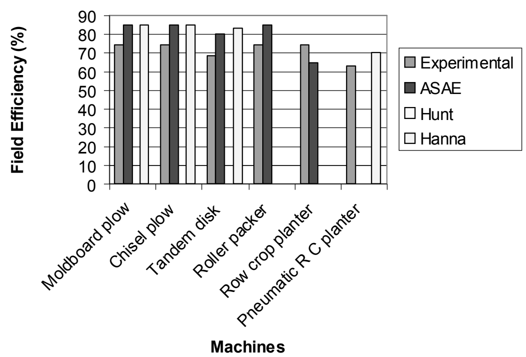

Figure 1. Comparison of the experimental field efficiency and the cited values.

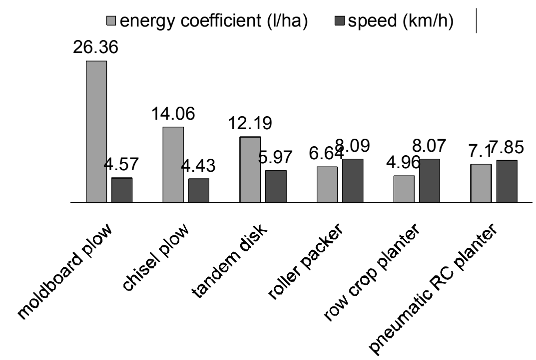

Figure 2. Energy coefficients at the speeds for different machines.

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