

## WORKABILITY AND MACHINERY PERFORMANCE FOR WHEAT HARVESTING

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### ABSTRACT

*The present study was carried out to evaluate three harvesting systems based on machine and workability of the operations performance for wheat production. Wheat is the most unique of all grain crops in its adaptability to harvested in different method. Three methods under study are evaluated, namely: green combine-bagger or tank (first method; reaper + thresher (second method) and the manual (third method). The evaluation of harvesting systems involves a number of modeling approaches and the models fall into: The first is evaluating machine performance by measuring machine capacity and the labour requirement. The second parameter is workability, which is calculated measuring the two mean factors, mainly, the length of harvesting period and potential harvesting hours. The third is economical evolution which is done calculating fixed costs, operating costs and optimal harvesting capacity. It is important that unproductive work be minimized. Therefore, Optimum harvesting operations as well as good systems is needed to minimize the cost and obtain maximum profits. The required of the labour number for three systems under studies were 5; 2; 15 and 23 labour per harvesting systems for combine with tank, combine with bagger, "reaper + thresher" and "manual + thresher" systems respectively. Also, the total manual energy required "kW.h/ton" recorded 0.8 kW.h/fed while; it was about 6.73 kW.h/fed for the manual system. Regarding to the purchase price of combine machine, the power per unite area is very small but the inertia cost is very height.*

### INTRODUCTION

**L**abour and machinery dominate all other cost categories in arable farming and much is to be gained by adapting and balancing resources according to the actual needs arising from farm size, crop plan, etc. In this situation, wheat harvesting is a good example of

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compromise machinery management, highlighting the inherent complex evaluations. Ismail et al. (2009) indicted that the harvesting costs make up 35% of the total machinery costs. This emphasizes the need for developing robust methods for choosing the optimal harvesting equipment.

The analysis and prediction of agricultural machinery performance are important aspects of all machinery management efforts (Witney, 1995). Abdel-Mageed et al. (1987) mentioned that almost every agricultural operation required for successful crop production must be timely. Untimely completion of any of these operations will cause a substantial loss of yield and quality, which ultimately will affect the farm's income. This loss is termed "timeliness penalty" or "timeliness cost". Edward and Boehye (1980) developed a simulation model to estimate net machinery costs for corn-soybean farms. They found that increasing farm size (both area of crops and labour supply) increased the size of the least. Cost machinery sets to the greatest degree and decreasing the proportion of labour and field hours available per land unit had the next most significant (positive) effect on the least.

Although there are numerous data depicting the net capacity of combines, on-farm surveys show that the actual field performance differs considerably. When field operations, such as harvesting, are analyzed the primary activity is that of carrying out the operation. Although some nonproductive activities (turning time, adjustment time, etc.) are unavoidable, the goal is to minimize the sum of these nonproductive activities, as they may total as much as 40% (Henrichsmeyer et al., 1995). **Elrick (1982)** stated that the slowest 10% of combine operators are only half as fast as the fastest 10% over the whole harvest season when the same combine model is used.

One of the most crucial pieces of information for determining machinery sizes is the number of potential field working hours (e.g., Audsley, 1984 and Ekman, 2000) contained within the term workability. Previous working-days criteria for combine harvesting include threshold values for past amounts of rainfall (Audsley and Boyce, 1974) and the combination of rainfall thresholds and algorithms for grain moisture content (e.g., Philips and O'Callaghan, 1974 and Atzema, 1994). Explanatory models suggest

that prediction using grain moisture content, in conjunction with meteorological data, is the most promising working-day criterion, especially if operates on an hourly basis (e.g., Goense, 1987; Atzema, 1990). Previous efforts have included a number of modeling approaches to support farm machinery selection. The approaches involved simulation (e.g., Soerensen (2003); Srivastava *et al.* (2006); Nilsson (1987) De Toro and Hansson (2004) and Witney (1995), linear programming techniques (e.g., Nilsson, 1972; Bender *et al.*, 1990; Jannot and Cairol, 1994; Parmar *et al.*, 1996), or a combination of these modeling and solution techniques (Tsai *et al.*, 1987).

The approach described here involves an analysis and modeling of the harvesting operation based on a level of aggregation consistent with the accessible data related to machinery performance and workability. The machine performance is based on detailed farm-specific task time models and the workability is based on calculate the length of harvesting period and potential harvesting hours models.

### **METHODOLOGY**

Three different systems were used to harvesting wheat croup, namely the Combine machine model Deutz Fahr 660, with two storage types (tank and bagger), Reaper machine (ITT-CRS) to cutting the crop and threshed using thresher machine model HMT/1987 and finally manual (harvester+thresher) system. The specification of the used machines tabulates in table (1). Under all calculations the specification of tractors is found in the table (2). The evaluation of harvesting systems involves a number of modeling approaches and the models fall into the following categories:-

#### **Machine performance**

The machine performances for all different types under study were evaluated measuring machine capacity and the labour requirement.

#### **Workability**

The second parameter is workability, which is calculated measuring the two mean factors, mainly, the length of harvesting period and potential harvesting hours.

#### **Economics**

The economic evolution is done calculating fixed costs, operating costs and optimal harvesting capacity

### **The overall field capacity**

The total time for each machine used in the harvesting process was divided into time elements. These time elements included operation time (effective field time, turning time, unloading, etc.), ancillary time (adjustments, repairs, disturbances due to crop or soil, relaxation allowance, etc.), waiting time and preparation time. Then the overall field capacity (OC, fed/h) is calculated from the following equation:-

$$OC = \frac{60}{\left[ \frac{h \times 252}{v \times e} + \frac{p \times b \times n}{2e} + k + [(s \times h) \times \frac{1}{h}] + \left( \frac{m \times u \times 1000}{l} + (u \times c) \right) \right]} \times (1 + q) \quad (1)$$

Where;

h is the size of field (fed),

v is the working speed (km/h),

e is the effective working width (m),

p is the time for turning (min),

b is the field width (m),

n is the number of turnings,

k is the turnings on treatment of headland (min),

s the time of adjustments, control, tending of machine, etc. (min),

m is the preparation for unloading (min),

u is the expected yield (ton/fed),

l is the net tank size (kg),

c is the net unit of unloading time (min), and

q is an assessed rest allowance time amounting to 5% additional time (min)

Most statistical information on combines presents the combine net capacity in terms of the harvesting speeds (Elrick, 1982; Lundin and Claesson, 1985).

### **The wheat harvesting efficiency**

Based on the developed model, the harvester performance in terms of theoretical and gross capacities was estimated. The theoretical capacity was determined as the capacity when driving in the swath with full header width and average harvesting speed at standard loss levels (<2%).

Table (1): Specification of harvesting machines

Machines Items	Reaper	Thresher	Multi-purpose combine
<b>Model</b>	1986 ITT/CRS	HMT/1987	Deutz Fahr 660
<b>Working width</b>	1.5 m	2.0 m	2.0 m
<b>Width</b>	2430 mm	2090 mm	3.48 m
<b>Length</b>	2982 mm	2300 mm	8.16 m
<b>Height</b>	720 mm	2350 mm	3.58 m
<b>Weight</b>	200 kg	1445 kg	5100 kg
<b>Source of power</b>	Tractor PTO shaft	Tractor PTO shaft	4 cylinder engine
<b>Source of manufacture</b>	Local	Turkish	Germany
<b>Max. Power output</b>	----	----	63 hp
<b>Drum speed</b>		800 rpm	

Overall, the gross capacity takes into account the complete operational cycle, including all turnings, unloading, occasional stops, rest allowances, etc., as identified by the on-farm measurements.

Table (2): The tractor specifications

Items	Specifications
Country paternity	Romanian
Power: at PTO (factory observed at 2100 rpm)	(76HP)
Type	Diesel
<b>Cylinders:</b>	4 In Line
Slow idle speed	850+ 50 rpm
High idle speed	2275+ 50 rpm
Bore and stroke	115.9 x120.6 mm.
Compression ratio	15.8 : 1.0
Displacement:	7.6 L
Firing order	1 – 3 – 2 – 4
Valve Clearance Intake & Exhaust	0.38 mm 0.51 mm.
Lubrication system	Full pressure - full flow filtration
Mass	3930 kg
Top of steering wheel	2929 mm
<b>Hydraulic system</b>	
Maximum pressure	200 bar
<b>Electrical system:</b>	
Batteries	12 volt in parallel
Alternator	140 Amp.
Gear selections:	4 forward, 1. Reverse 2. Methods

Summarizing, the efficiency of the harvesting operation is expressed by the field efficiency factor (*FE*). This factor, denoting the fraction of the actual

operational combining time spent on productive work, was estimated as the ratio of the gross capacity to the theoretical capacity.

**Energy requirements**

The power consumption (Er, kW) for different systems were calculated according to the following equation (Hunt- 1995)

$$Er = Fc \left( \frac{1}{60 \times 60} \right) P \times LCV \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}; \quad \text{kW} \quad \dots\dots (2)$$

Where:

- Fc = the fuel consumption L/h
- P.F = the fuel density, kg/L (for solar = 0.85)
- L.C.V. = the lowest calorific value of fuel (k<sub>cal</sub>/kg) average L.C.V of diesel is 11000 k<sub>cal</sub>/kg)
- η<sub>th</sub> = the thermal efficiency of the engine, (considered to be about 35% for diesel engine)
- 427 = thermo-mechanical equivalent, kg.m/kcal
- η<sub>m</sub> = the mechanical efficiency of the engine, (considered to be 80% for diesel engine)

So, the energy can be calculated as following:

$$\text{Energy requirement} = \frac{\text{Engine power (kW)}}{\text{Production (kg/h)}} \quad \text{kW.h/kg} \quad (3)$$

Manual energy: the manual energy (E<sub>H</sub>) per feddan was calculated by considering the power of one labour about 0.1 hp, Chancellor (1981).

$$E_H = \frac{0.1 \times 0.74 \times N_L}{P_a} = \frac{N_L}{P_a} \times 0.0746 \quad \text{kW.h/fed} \quad (4)$$

Where:

- 0.1 = hp of agricultural labour (hp/man)
- N<sub>L</sub> = number of labour
- P<sub>a</sub> = actual productivity (fed/h)
- 0.746 = co-efficiently per conversion from hp to kW.

**The wheat harvesting machinery costs**

The current economic model focuses on the system costs, including both machinery costs (fixed and variable) as well as repair and maintenance

costs. The model is derived from theories described by Nilson (1972), Have (1991) and Hunt (1995), and expresses the total yearly fixed and variable costs as a function of machine capacity:

$$C = \left[ \psi \times \rho \times \theta + \frac{A \times U}{\theta \times FE} \times (r \times \rho \times \theta + L + \delta \times \theta) \right] / Pr \quad (5)$$

Where;

- C is the total yearly costs (LE/ton),
- $\psi$  is a factor expressing depreciation and interest as a fraction of the purchase price, (1/year)
- $\rho$  is the purchase price per unit capacity (LE.h/ton),
- $\theta$  is the machine capacity (ton/h),
- A is the treated seasonal area (fed/year),
- U is the expected crop yield (ton/fed),
- FE is the field efficiency expressing the ratio between gross and theoretical capacity,
- r is a factor expressing repair and maintenance costs as a fraction of purchase price (table 3),
- $\delta$  is the fuel costs proportional to the capacity (LE/h), and
- Pr is process productivity (ton).

The unit price of harvesting one ton wheat (HOTW) for different harvesting systems was derived from relating Equation (5) to the purchase price of combines on the market with varying drum widths (Agrimach, 2002). The parameters of calculated costs are found as shown in table (3);

Table (3): Implement service costs

Items Type of machines	Purchase price (LE)	Live time		Maint. and repairs cost, of new machine price, %
		Year	H	
Tractor 45 hp	60000	10	10000	90
Reaper tractor mounted	7000	10	1500	80
Thresher	10000	10	1500	65
Combine	300000	10	2500	60

## RESULTS AND DISCUSSION

### **The machine capacity and labour requirement**

It is important that unproductive work be minimized. The proportion of the productive time during the operational cycle is expressed as the field efficiency factor (FE). The "FE" was estimated for the ranges of capacities measured on the farm studies. Average results from these estimations were used for the machinery sizing scenario (table 4). The data in table (4) indicated that the field efficiency decreased with increasing the harvesting speed for all different harvesting systems. Whereas, the losses time of harvesting is inversely proportional with operation speed. Compared the "reaper + thresher" harvesting system with the manual system, indicated the closed differences between them. The operation times per fed. recorded 0.385; 0.357; 6.65 and 12.15 h/fed for combine with tank, combine with bagger, "reaper + thresher" and "manual + thresher" systems respectively (table 5).

The required of the labour number for three systems under studies are tabulated in table (5). There were 5; 2; 15 and 23 labour per harvesting systems for combine with tank, combine with bagger, "reaper + thresher" and "manual + thresher" systems respectively. Also, the table (5) includes the total manual energy required per ton "kW.h/ton" to harvest one fed. From table, the total energy for combine harvester recorded 0.8 kW.h/fed while; it was about 6.73 kW.h/fed for the manual system. Regarding to the purchase price of combine machine, the power per unite area is very small but the inertia cost is very height.

### **Energy requirements**

The energy requirements for different harvesting systems were calculated for manual (human energy) and mechanical. The human energy is tabulated in table 4. Which, it indicated that the human energy per fed for the third system is about 6.42 kW.h whereas for the first system is about 0.144 kW.h per fed. The mechanical energy is illustrated in table (6). From table, it may be notes that, the mechanical energy for the third harvesting systems is very low comparative with the first one. But, the total energy indicated the inverse of the above results.



Table (4): The field capacity and field efficiency

Harvesting methods		Speed	Operating time h/fed	Turn time h/fed	Empt. Time h/fed	Total time h/fed	Act. Field capacity fed/h	Theo. F.C fed/h	Field efficiency %
Comb.	tank	1.96	0.582	0.072	--	0.654	1.529	1.99	76.83
		3.19	0.358	0.072	--	0.430	2.32	3.23	71.82
		4.0	0.285	0.072	--	0.357	2.801	4.06	68.99
	bagger	1.99	0.568	0.068	0.038	0.674	1.485	2.02	73.51
		3.31	0.340	0.068	0.038	0.446	2.237	3.36	66.58
		4.12	0.279	0.068	0.038	0.385	2.599	4.11	63.24
Reaper		3.10	1.04	0.1	--	1.14	0.880	1.13	75.00
		4.20	0.80	0.1	--	0.90	1.11	1.53	72.42
		4.90	0.663	0.1	--	0.763	1.31	1.86	70.31
Manual			3.15	--	--	3.15	0.317	----	-----

Table (5): The manual energy requirements "kW.h/fed"

Harvesting systems	Items	No. of labour	Total No	Manual energy kW	Total manual time h/fed	Total manual energy kW.h/fed
Combine (system-1)	Bagger	5	5	0.373	0.385	0.144
	Tank	2	2	0.149	0.357	0.053
Reaper + threshing (system-2)	Collect yield	8	15	0.597	3.50	2.089
	Threshing	7		0.522	3.15	1.644
Manual + thrusting (system-3)	Cutting	8	23	0.597	5.00	2.985
	Collect yield	6		0.448	4.00	1.792
	Threshing	7		0.522	3.15	1.644

Table (6): The mechanical energy "kW h/fed" for three systems

Speed \ Harvesting methods		Total time h/fed	Act. fuel consumed L/h	Mechanical power kW	Mechanical energy kWh/fed	Total energy kW.h/fed	
Combine (system-1)	tank	1.96	0.654	10.09	101.18	66.17	
		3.19	0.430	11.59	116.22	49.97	
		4.0	0.357	12.25	122.84	43.85	43.994
	bagger	1.99	0.674	12.70	127.36	85.84	
		3.31	0.446	13.55	135.88	60.60	
		4.12	0.385	13.95	139.89	53.86	53.913
Reaper + Threshing (system-1)		3.10	1.14	4.20	42.12	48.02	50.109
		4.20	0.90	4.70	47.13	42.42	44.064
		4.90	0.763	5.00	50.14	38.26	41.245
		-----	3.15	4.53	45.43	143.10	144.892
Manual +threshing (system-1)	-----	3.15	4.53	45.43	143.10	144.744	

**The wheat harvesting machinery costs**

The costs of labour during wheat harvesting under different systems is calculated in table (7) while the costs for one ton of wheat yield (k.W h/ton - and LE/ton) is found in table (8). The cost of human were 0.334; 0.057; 7.25 and 19.52 kWh/ton per harvesting systems for combine with tank, combine with bagger, "reaper + thresher" and "manual + thresher" systems respectively. While, the total costs required per ton "LE/ton" were about 88.57; 87.25; 82.4 and 110.25 LE/ton for harvesting systems for combine with tank, combine with bagger, "reaper + thresher" and "manual + thresher" systems respectively.

Table (7): The costs of labour during wheat harvesting under different systems

Harvesting systems	Items	Daily hair LE/day	Total daily hair LE/day	Total time h/fed	Total energy kW.h/ton
Combine (system-1)	Bagger	15.0	75.0	2.15	0.344
	Tank	15.0	30.0	0.90	0.0574
Reaper + threshing (system-2)	Collect yield	15.0	120.0	9.10	2.329
	Threshing	15.0	105.0	22.00	4.923
Manual + thrusting (system-3)	Cutting	15.0	120.0	40.00	10.238
	Collect yield	15.0	90.0	24.00	4.609
	Threshing	15.0	105.0	22.00	4.923

Table (8): The costs and energy requirement for one unite of the yield (k.w h/ton - and LE/ton)

harvesting methods	items	Machine costs L.E/h	Daily Hire L E/h	total costs L E/h	K w h/ fed			Total time h/fed	The total costs of the yield	
					Manu Energy	mech. energy	Total energy		kw h/ton	LE/ton
Combine (system-1)	Tank	164.35	42.02	206.37	0.050	43.85	43.90	0.357	18.84	88.476
	bagger	164.35	38.96	203.31	0.140	53.86	54.00	0.385	23.18	87.164
	Total									
Reaper + threshing (system-2)	reaper	32.90	19.66	52.56	2.089	38.26	40.349	0.763	17.32	22.534
	thresher	31.55	4.775	36.325	1.644	143.10	144.744	3.15	62.12	15.573
	Total	64.45	24.435	88.885		181.36				38.107
Manual + thrusting (system-3)	manual	--	192.00	192.00	4.777	--	4.777	64.00	2.05	82.315
	thresher	31.55	33.33	64.88	1.644	143.10	144.744	3.15	62.12	27.816
	Total	31.55	36.33	67.88		143.10				110.131

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## المخلص العربي

## الأداء التشغيلي لآلات حصاد القمح

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يتناول البحث تحديد القدرة الفعلية لاختبار انطباق نظم الحصاد حيث تناول البحث ثلاث من النظم الشائعة الاستخدام في الريف المصري وهي استخدام اله الحصاد المركبة لنوعين (ذات تجميع الحبوب في خزان المعدة- ذات التعبئة في أجولة) ويطلق علي هذا النظام بالأسلوب الأول- أما الأسلوب الثاني هو استخدام (محشه تجميع + اله الدراس ) أما الأسلوب الثالث لحصاد محصول القمح هو استخدام (المنجلة اليدوية في تجميع القمح + عمال للنقل ونشر المحصول + استخدام وحدة الدراس ). تناول التقييم تحديد السعة الحقلية والكفاءة بالإضافة الي التقييم الاقتصادي. ولتحديد نظم التقييم المختلفة استخدم كثير من النماذج الرياضية. حيث تم تحديد القدرة المنتجة لوحدة الفدان -تحديد استهلاك الوقود-تحديد الطاقة اليدوية والميكانيكية لإنتاج وحدة الطن من القمح. تبين من نتائج البحث أن عدد العمالة لتنفيذ برنامج العمل هو ٥ و ٢ و ١٥ و ٢٠ عامل علي الترتيب وان اجمالي التكاليف الكلية لإنتاج طن من الحبوب هو ٨٨.٤٧ و ٨٧.١٦ و ٣٨.١٠ و ١١٠.١٣ جنية مصري لكل واحد طن من الحبوب.

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