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System Approach to Machinery Selection (Saudi Agriculture Case)

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ABSTRACT. In Saudi Arabian agriculture the selection and determination of the optimum size, power and quantity of machinery do not obey established rules and principles. This study aims at setting a scientific basis for selecting the proper size of the tractor which suits the local agricultural characteristics and the related resources of production. Experimental work included testing the performance of a 30 kw tractor during the execution of three typical agricultural operations namely the primary tillage, the secondary tillage and planting. The obtained data were used to select the appropriate tractor for an objective function which was the overall rate of energy conversion. The analysis of the experimental and mathematically obtained data revealed that the 50 kw tractor was the optimum tractor for the conditions of Saudi agriculture. The decrease in the degree of mechanization of Saudi agriculture was found to be 0.393 k w/ha. The required number of the recommended power level tractors to achieve full mechanization was determined to be 3870 tractors.

The involvement of any government in mechanization programs eventually aims at enabling the farmers to introduce and economically use farm machinery by themselves. This is a long term program undertaken for the overall development and the costs are often immaterial compared to the desired results. Irrespective of these considerations, especially in developing countries, the government participation occupies the first place in introducing mechanization, either on a short term or a long term basis. This role is evident in the Kingdom of Saudi Arabia when reviewing the annual report 1402/1403 A.H., of Saudi Arabian Agricultural Bank (1983) which reveals that farm machinery ranked second after projects with respect to the size of demand. Loans for farm machinery amounted to S.R. 821.273.316 or

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19.7% of total loans. In recent years the Saudi Arabian agriculture has been shifting from a traditional to a scientific farming systems. This reflects the fact that there has been a distinct change in the thinking of the Saudi Arabian farmers moving from traditional, low productivity farming to a modern, high productivity potential farming subjected to technological limitations.

The new high-yielding agricultural production technology requires judicious management of resources at the disposal of the farm operator, especially for farm mechanization which plays a crucial role in increasing the resource productivity. It is important for agricultural scientists in Saudi Arabia and in other developing countries, especially machinery management specialists, to focus their attention on this urgent problem and to evaluate the economic benefits resulting from better machinery management.

The basic approach to the problem of selecting the proper size of machine is to consider the machine as an object into which the owners put money, in the form of capital investment, fuel, oil, maintenance, repair and labor. Then, to evaluate the outputs in the form of improvement and modification in their crop production system.

Selections of the appropriate qualitative and quantitative needs concerning agricultural mechanization units have been discussed in the works of Link (1967), Krutz *et al.* (1977), Younis (1980) and Ozkan and Frisby (1981).

In Saudi Arabian agriculture there is no clear rules and principles in selection and determination of the optimum size, power and quantity of both implement and tractors. It is usually a matter of trade which goes according to the condition of the machinery market whether it is local or international.

The purpose of this study is to establish the scientific basis to select the proper size of tractor which suits the local agricultural characteristics and the related resources of production.

Methods

Experiments were carried out at the Agricultural Experimental Station of the College of Agriculture, King Saud University in Dirab. Experimental work included testing the performance of a John Deere-1030 tractor of 30 kw power level. The attached implements were mouldboard plough, spike tooth harrow and grain drill. Primary tillage, considered as the most power consuming operation, was executed in a sandy loam soil at a depth of 15 cm and a forward speed of 4 km/hr. The specific soil resistance was calculated using the records of a drawbar dynamometer (STATIMETER-model B, 50 kw capacity). The dynamometer was attached between the tractor and the implement. The soil resistance was calculated for the tilled cross-sectional area (the mouldboard plough), mass (the spike tooth harrow) and number of drilled rows (the grain drill).

The overall field efficiency expresses the level at which the operator overcomes the difficulties leading to the decrease in productivity whether they are due to the machine, the land or the operator himself. To evaluate all the previous causes affecting efficiency, a time balance was done during several passes of each implement and the value of the overall field efficiency was calculated according to Hanna and Younis (1979).

The available P.T.O. shaft power of the tractor was measured using a P.T.O. hydraulic dynamometer (FROUDE, DPXZ, max kw 112).

The fuel consumption during the work of the mechanization unit was calculated by measuring the quantity of fuel required to refill the fuel tank after the working period. A graduated glass cylinder was used to measure the added quantity of fuel.

The results of the experimental work with the 30 kw tractor were used, as input data, to select the suitable implements to execute the three important operations; *i.e.* primary tillage, secondary tillage and planting, compatible with one of the tested power levels which were 30,40,50 and 60 kw.

It was assumed that the Weight-Power ratio of the tractor remains almostly constant as the power level increases. This assumption was made as the new trends in manufacturing modern tractors aim at keeping the weight of the tractor as light as possible and to have the Weight-Power ratios with insignificant differences among the competing manufacturing companies (1984). Figure 1 shows the flow-chart of selecting the implement. It was also assumed that the maximum plough width could not exceed 204 cm corresponding to 6 plough bottoms, each of 34 cm width. This assumption was made according to the power level of the available tractors, the technical ability of labor participating in the performance of the operation, and the technological requirements for the executed operation.

Any specified tractor could pull the plough was consequently considered suitable for the other farm machine of proper width. Checking the computed width started with the largest available width in order to make full use of the available tractor power. If the previously specified tractor could not pull the implement because of power limitation, the power level could be increased and the loop continued. If the computed width fell between two available widths, the smaller width was chosen, considering that the range of loading might fall between 60 and 85% of the maximum available to avoid overloading the tractor. Then, the output results about actual field capacity and energy consumption were obtained.

In order to determine the most appropriate tractor, the overall rate of energy conversion in MKJ/St.ha. was chosen to be the criteria of selection. This term is defined as the result of dividing the energy consumed in producing useful work in MKJ/hr. over the amount of the executed work in Standard hectares (St.ha.). The standard hectare is the area ploughed in one hour using mouldboard plough to a depth of 20 cm at a working speed of 4 km/hr powered with a 50 kw P.T.O. tractor,

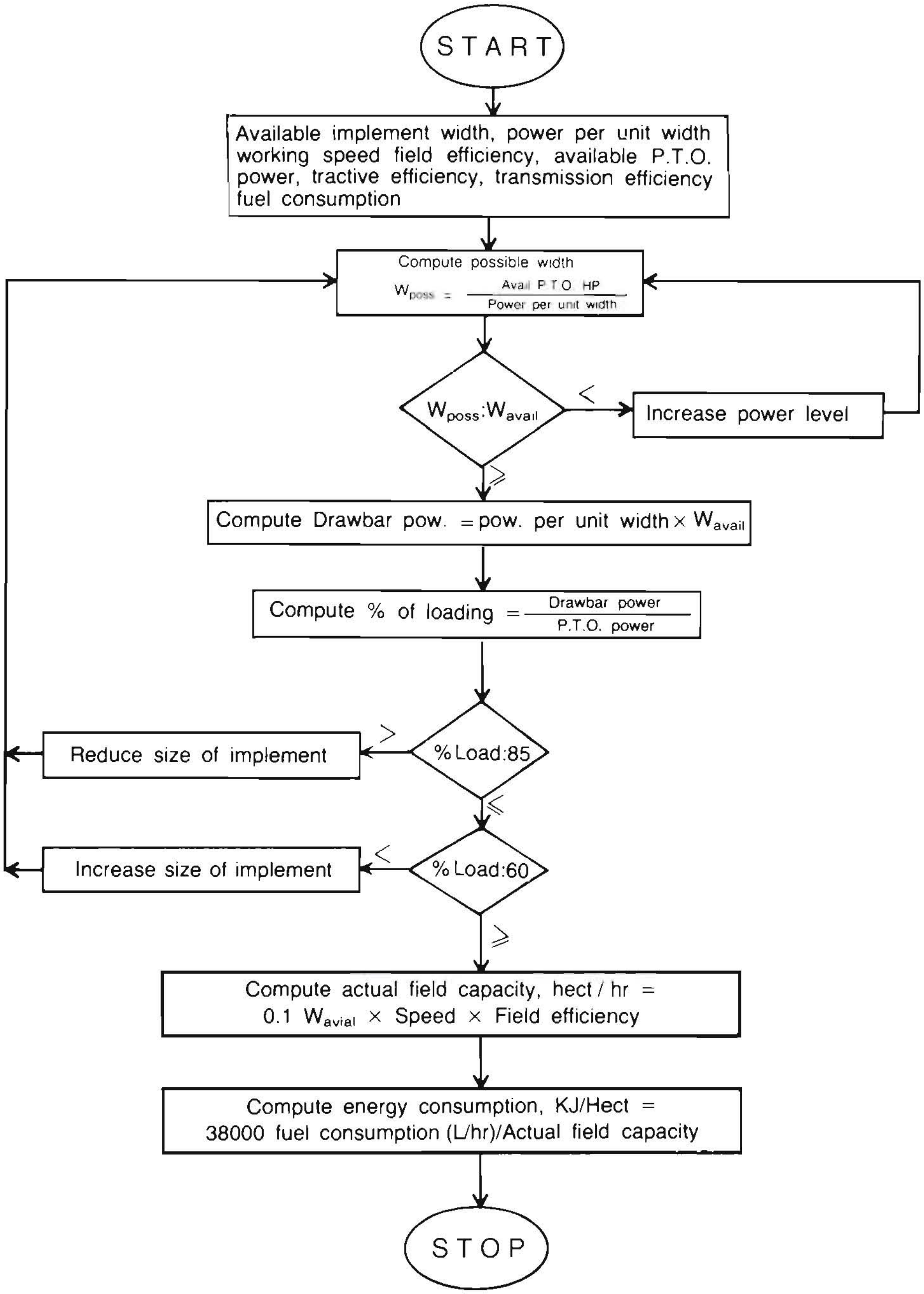

Fig. 1. Flow chart of selecting the implement.

(Flacof 1968). Accordingly, the actual field capacities in hectare per hour were converted to standard hectares using the listed coefficients of conversion found by Flacof (1968). These coefficients reflect the proportion of energy consumed in each operation compared with the energy consumed in the standard operation of mouldboard ploughing. For the conditions of executing the three tested operations, the coefficients of conversion of 1.0 for primary tillage, 0.81 for secondary tillage and 0.22 for grain drilling were selected according to Flacof.

Results and Discussion

The most important factors affecting the energy consumption are the type of soil, maintenance of the mechanization unit, setting of implement, and the skill of the operator. In addition, all these factors indirectly affected the field capacity of the mechanization unit expressed in the matching of mechanization unit components, in the overall field efficiency and in the utilization of the implement width. Table 1 summarizes the obtained results of the carried out field experiments for the operations of primary tillage, secondary tillage and grain drilling with the John Deere-1030, 30 kw power level tractor. The Table also gives the calculated values of the field capacities in hectares and in standard hectares.

According to the data of Table 1, the total amount of the consumed fuel by the 30 kw tractor through executing the three tested operations was 81.68 1/hr. This amount is equivalent to 1.201 MKJ/hr*. On the other hand, the total amount of the work output in the same case was 1.095 St.ha/hr. Thus, the overall rate of energy conversion of the 30 kw power level tractor was 1.201 ÷ 1.095 = 1.096 MKJ/St.ha.

As to the other power levels (40, 50, 60 kw), it is noticed that the increase of power level is accomplished by the increase of workable width of the implement, fuel consumption and consequently the input energy increased which yielded in a lower value for the overall rate of energy conversion. This may be due to that the increase in power level was not sufficient enough to increase the width of the plough, but may be high enough to increase the width of the harrow and the width of the grain drill. These two last operations have lower values of coefficient of conversion. Table 2 gives the value of the overall rate of energy conversion for the tested power levels.

When the tractor power was increased from 30 kw to 40 kw and the width of the utilized harrow was increased, the total work output was increased by 0.175 st.ha. (from 1.095 to 1.270). The rate of increase of both energy cost and work return were different enough to cause about 0.18% positive decrease in the overall rate of energy conversion (from 1.096 to 1.094). On the other hand, the work

* 1 1/hr = 38000 KJ/hr.

Table 1. Parameters of farm mechanization units through executing the field experiments.

Operation	Mechanization Unit		Parameters							
	Tractor	Implement	Draft N/cm	Fuel l/hr	Width m	Speed km/hr	Overall field Eff. %	Actual F.C. ha/hr	Coeff. of conver-sion	Actual F.C. St./ha/hr
Primary Tillage	John Deere 1030	Mouldboard Pl. ALPUEMA ARADO 2 × 14	38.0	11.8	0.75	4.0	77	0.231	1.00	0.231
Secondary Tillage	John Deere 1030	Spike tooth harr. KONGSKLIDE DC-2919	12.0	12.6	2.50	4.0	80	0.800	0.81	0.648
Grain Drilling	John Deere 1030	Grain Drill Nordsten 25 × 4.5	1.2	7.2	2.80	4.0	70	0.980	0.22	0.216

Table 2. Relation between power levels and overall rate of energy conversion

Parameter	Tractor power level, kw			
	30	40	50	60
Total energy input				
l/hr	31.600	36.600	39.600	52.500
MKJ/hr	1.201	1.390	1.505	1.995
Total work output				
ha/hr	2.011	2.189	2.668	2.900
St.ha//hr	1.095	1.270	1.634	1.863
Overall rate of energy conversion, MKJ/St.ha.	1.096	1.094	0.921	1.071

return has increased more rapidly when the 50 kw tractor allowed the increase in the width of all the utilized implement. The amount of increase in total work output by the 50 kw tractor was 0.539 and 0.364 St.ha/hr compared with that by the 30 and 40 kw respectively. The overall rate of energy conversion improved by 0.175 and 0.173 MKJ/St.ha. by using the 50 kw tractor when compared with the 30 kw and 40 kw tractors respectively. However, this trend, in the improvement of the overall rate of energy conversion by increasing the power level, did not continue with other power levels beyond 50 kw. The 60 kw tractor consumed 52.500 liter of fuel per hour and produced only 1.863 St. ha/hr realizing worse value for the overall rate of energy conversion. Figures 2 and 3 illustrate the effect of increasing tractor power on the energy input and on the overall rate of energy conversion under the investigated conditions. By looking at the figures, one should not conclude that increasing power level always either increase at the same rate or decrease the energy input. This is because each time the tractor power was increased, more area was produced but the energy requirements for each unit area should not be equal.

From the previously mentioned findings and on energy basis the 50 kw tractor may be considered the optimal power source, regardless of the other items of costs of owning and operations, for the conditions under consideration. Any change in the inputs may result in different recommendations. This may be a vital subject of further study.

Degree of mechanization is defined as the number of power units working on the unit area of the land. Power units include all power resources whether they are mechanical or biological. Based on the data obtained from the Ministry of Agriculture and according to the reports of the Saudi Arabian Agricultural Bank, the actually utilized power in tractors and self-propelled machines amounts to

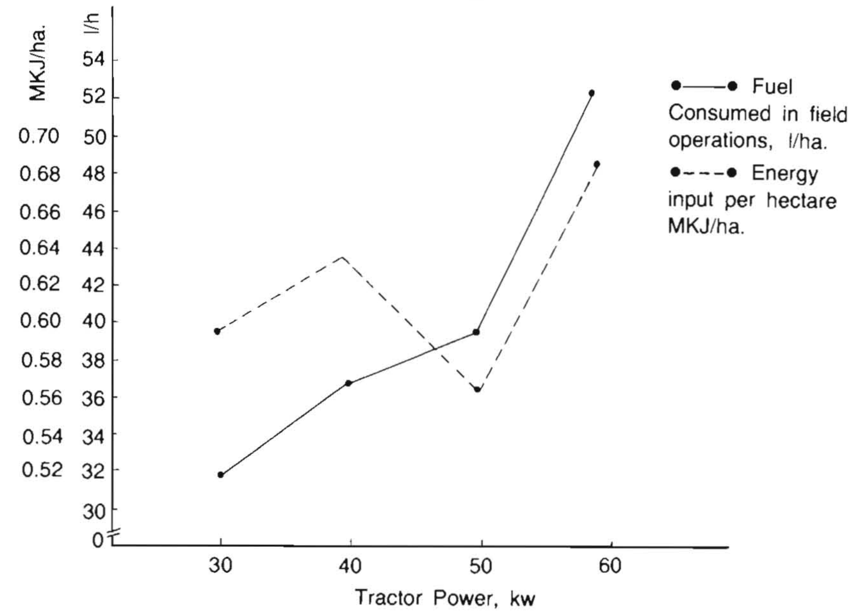

Fig. 2. Effect of tractor power on energy input

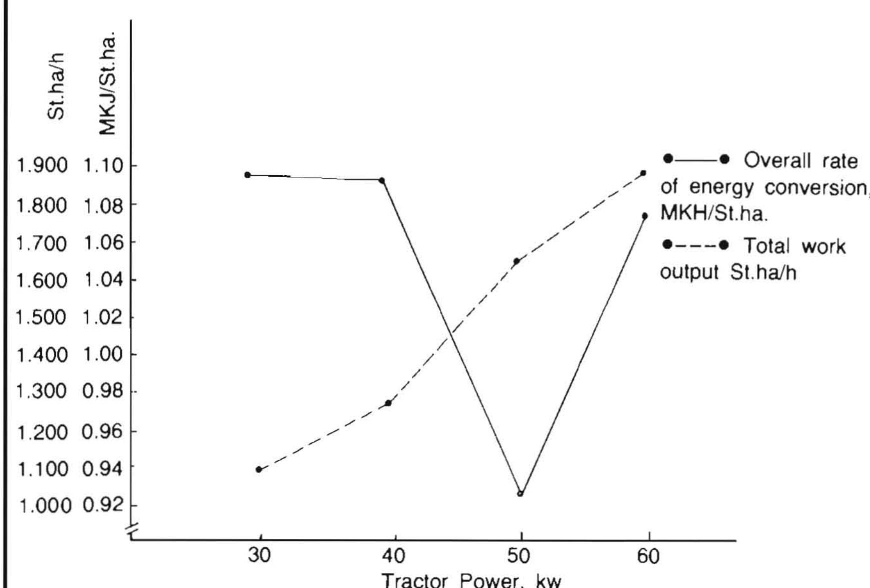

Fig. 3. Effect of tractor power on energy conversion

about 73450 kw. The number of the agricultural workers sharing in the production yields about 126546 kw. The role of animals in producing power is neglected. Thus, the total power utilized is 200086 kw over a present cultivated area of 492300 hectares. Consequently the degree of mechanization is 0.407 kw/ha. It was stated that the power available per unit area over much of the developed countries in Europe, Asia and America ranged from 1.8 to 3.2 kw/ha. (Giles 1975). In developing area such as Africa, Crosseley (1979) mentioned that the degree of mechanization is about 0.04 kw/ha. and a tenfold increase in power, to 0.4 kw/ha. is neecessary. Therefore, in the conditions of Saudi agriculture it is suggested to provide an arbitrary power of 0.8 kw/ha. in order to achieve reasonable productivity.

Accordingly, the increase in the current power to achieve a degree of mechanization of 0.8 kw/ha. is the difference between the present degree and the objective degree, i.e.

The raise in degree of mechanization = 0.800 − 0.407	= 0.393 kw/ha.
The cultivated area	= 492300 ha.
The total power required for realizing full mechanization in the current cultivated area	= 0.393×492300
	= 193473.9 kw

This amount of excess power can be realized by adding new tractors of the recommended power level.

Thus, the number of required 50 kw tractors = 193473.9 ÷ 50
= 3870 tractors

Introducing this additional number of 50 kw power tractors will have significant impact upon the technical and economical aspects of the agricultural mechanization in the Kingdom of Saudi Arabia, which may be available subject for further study.

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مدخل تحليلي لاختيار وحدات الميكنة الزراعية بالزراعة السعودية

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تضطلع الدول بمهام أساسية ضمن خططها الهادفة إلى إدخال الميكنة الزراعية وتطبيقها بشكل اقتصادي يخفف العبء عن المزارعين الراغبين في استخدام الميكنة الزراعية. وفي المملكة العربية السعودية احتل نصيب وحدات الميكنة الزراعية المرتبة الثانية من إجمالي إنفاق البنك الزراعي السعودي خلال عام ١٩٨٣ ولكن توفير هذه الوحدات ما زال يتم بأسلوب غير مستوفي للأساس العلمي للاختيار الكمي والنوعي.

تهدف هذه الدراسة إلى وضع الأسس العلمية لاختيار الجرار المناسب والذي تتفق قدرته مع الخصائص الزراعية وعناصر الإنتاج الزراعي المتاحة. أجريت التجارب الحقلية في محطة التجارب الزراعية بديراب والتابعة لكلية الزراعة ـ جامعة الملك سعود وشمل برنامج التجارب اختبار أداء جرارات ذات مستويات قدرة مختلفة عند قيامها بتنفيذ العمليات الزراعية الأكثر استهلاكاً للطاقة واختيرت عمليات الحرث بالمحراث القلاب المطرحي والتمشيط بالمشط ذو الأسنان الصلبة وزراعة الحبوب كمثال للعمليات الزراعية. أثناء عمل وحدات الميكنة تم أخذ بيانات لحساب بعض

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مؤشرات الأداء مثل المقاومة النوعية للتربة (بواسطة دينامومتر القدرة على عمود الجر)، الكفاءة الحقلية الكلية لوحدات الميكنة الزراعية (بعمل ميزان زمني لوقت عملها)، القدرة على عمود الإدارة الخلفي بواسطة دينامومتر قدرة عمود الإدارة الخلفي)، استهلاك الوقود أثناء أداء العمليات الزراعية (بالطريقة الكمية). استخدمت البيانات المتحصل عليها من التجارب الحقلية في برنامج اختيار الجرار المناسب وذلك بتحديد دالة هدف هي معدل تحويل الطاقة المستهلكة إلى عمل مفيد. وللحصول على مقياس للعمل الناتج استخدم الهكتار القياسي كوحدة قياس ينسب إليه كل عمل ناتج من تشغيل وحدات الميكنة الزراعية.

ولقد تبين من مقارنة الطاقة المستهلكة والعمل الناتج ومعدل تحويل الطاقة لمستويات القدرة المختلفة موضع المقارنة (٣٠، ٤٠، ٥٠، ٦٠ كيلووات) أن مستوى القدرة ٥٠ كيلووات هو الأنسب للظروف موضع الدراسة حيث أنه يعطى أحسن معدل تحويل وهو ٠,٩٢١ ميجا كيلو وات / هكتار قياسي بمقارنته بالمستويات الأقل قدره وهي ٣٠، ٤٠ كيلو وات حيث أعطت ١,٢٣٢ ، ١,٠٩٤ ميجا كيلو وات / هكتار قياسي على الترتيب وبمستوى القدرة الأكبر وهو ٦٠ كيلو وات والذي أعطى : ٠,٩٣٤ ميجا كيلو وات / هكتار قياسي

ولتحديد احتياجات الزراعة السعودية من الجرارات المناسبة قدرت درجة الميكنة الزراعية الحالية ووجد أنها ٠,٣٤ كيلو وات / هكتار وأنها تقل بمقدار: ٠,٤٦ كيلو وات / هكتار عن المعدل العالمي والمجدي لتطبيق الميكنة الشاملة. لذلك حسبت أعداد الجرارات ذات مستوى قدره ٥٠ كيلو وات ووجد أنها تبلغ ٤٥٢٩ جرار يلزم إضافته إلى الموجود فعلاً

ليمكن تطبيق الميكنة الزراعية الشـاملة في الزراعـة السعوديـة وذلك على أساس أن أسلوب التخطيط المتبع هو لفـترة قصيرة الأجل تفترض الاحتفاظ بكل الموارد الإنتاجية الأخرى الحالية عـلى ما هـو عليه. تـوفير ذلـك العدد من الجـرارات المناسبـة سيكون له أثر كبير على الاتجاهـات الفنية والاقتصـادية لميكنـة الزراعة السعودية.