Journal of Engineering and Applied Sciences 12 (13): 3323-3328, 2017
ISSN: 1816-949X

Justification of the Tractor Fleet Range for the Agricultural Complex of Kazakhstan

[1]A. Usmanov, [1]V. Golikov, [2]V. Astafyev, [1]J. Utemuratov, [2]M. Ploxotenko and [2]S. Bobkov
[1]Kazakh Scientific Research Institute of Mechanization and Electrification of Agriculture, 050005 Almaty, Kazakhstan
[2]Kazakh Research Institute of Mechanization and Electrification of Agriculture, Kostanay Branch, 110011 Kostanay, Kazakhstan

Abstract: The range of tractor fleet for different regions of Kazakhstan is justified based on the calculations and analysis of tests results and observation. The results of research on the effect of the nominal tractive force (class) of tractors, the level of their reliability, the price and applied technology of tillage on labor productivity and cash expenditure are presented in this study. It is established that the application of zero tillage technology has the greatest impact on increasing labor productivity (2.5, ..., 3 times) compared to soil protection technology. Increasing the nominal tractive force of tractors from 40-50 to 60-80 kN and applying the minimum tillage technology provides an increase in labor productivity for 1.9, ..., 2 times and decrease in aggregate costs compared to soil protective technology.

Key words: Range, tractor fleet, tractive force, system of machinery, technology, area, unit, load, costs

INTRODUCTION

In recent years, positive development has been observed in the development of Kazakhstan's agricultural production which became possible due to the adopted program "Agrobusiness 2020". The concept of sustainable development of the Agroindustrial Complex (AIC) provides measures for the modernization and re-equipment of production, the development of its institutional and industrial infrastructures through the development of financial, investment, insurance, information institutions and the formation of industry clusters as well as ensuring safe and quality products in accordance with international requirements. The implementation of these measures will ensure the qualitative preparation of the agricultural sector to compete with imported products on the national market in the conditions of membership in the World Trade Organization (WTO) and prepare a serious springboard for the export of national products to foreign markets.

Over the decades, energy crisis is one of the most important concerns of human societies. This happens under conditions that consumption of fossil energy and the climatic pollutions and changes caused by it has been changed in to a problem that buildings can be considered as one of the most effective factors in accelerating this issue (Ghasemi, 2017).

The further development of AIC, aimed at increasing the productivity and profitability of its branches, requires the adoption of measures for the qualitative growth in technical equipment of the AIC, the observance of scientifically-based agrotechnologies, the strengthening of scientific support and the introduction of innovative developments in accordance with the needs of the real sector.

The founding document reflecting the fundamentals of scientific and technical progress in the agroindustrial complex, through which the coordinated activity of various organizations providing the agro-industrial complex with machines, equipment and new generation technologies including the creation of competitive samples in the world market is provided by the system of technologies and machines for cultivation agricultural crops (Esfahani *et al*., 2013).

The formation of a long-term technical policy based on the strategic approach serves as a powerful mechanism for the purposeful regulation of the country's economy by the state, interaction with the market environment and operating enterprises in this sphere with the aim of commercial efficiency of the industry. Implementation of the technical policy will be possible only if the competitiveness of agricultural machinery is increased and the technological potential is significantly upgraded.

Corresponding Author: J. Utemuratov, Kazakh Scientific Research Institute of Mechanization and Electrification of Agriculture, 050005 Almaty, Kazakhstan

Insecurity of agricultural machinery leads to violation of work technology, agrotechnical terms of their realization; it negatively affects spring field and harvesting work; leads to a shortage of 20, ..., 40% of the crop; affects the quality of land cultivation, reduces labor productivity; brings additional costs associated with non-rational consumption of fuel and lubricants. Improvement of the situation in the agroindustrial complex can be expected at the high level of advanced technology and modern agricultural machinery.

In connection with the fact that the main machine in the agroindustrial complex is a tractor, it is necessary to justify the range of tractor fleet in Kazakhstan.

MATERIALS AND METHODS

Objects and methods of research: The object of the study is Machine and Tractor Fleet (MTF), nomenclature of agricultural tractors classification, traction classes in the agroindustrial complex and its functioning in the agroindustrial complex.

During the research, theoretical methods based on the use of production processes system analysis, main provisions of MTU theory and agricultural machines and methods for estimating the economic efficiency of agricultural machinery were used.

For the analysis and justification of the tractor fleet range, the recommendations of the research institute of agriculture and experimental stations on perspective technologies of cultivation of agricultural crops, the works of the research institute and institute of higher education, monographs and other materials were used. The range of the tractor fleet for cultivation and harvesting of agricultural crops was selected depending on the size of the cultivated area.

The general methodology of the work is based on the system analysis of the production process as a system taking into account all the necessary internal interrelations. From the positions of system analysis, the justification of the tractor fleet includes conceptual, operational research and detailed description. In the course of conceptual research, the concept of a problem-solving system was developed and on the basis of analysis and decomposition of the system of goals, the goal of work was carried out. In the course of a detailed description, a description was made of the existing technical equipment of production processes, natural-production conditions, technologies, technical and operational characteristics of tractors. Under operational research, the choice was made of typical farms, the development and realization of the economic-mathematical model, justification for the structure of the tractor fleet for typical farms and the boundaries definition of the effective application of this tractor fleet. Synthesis of the most effective solutions ensured the construction of a problem-solving system.

An economic-mathematical model was implemented and aggregate costs were calculated, representing specific indicators (per 1 ha of the acreage or per ton of product received).

Analysis of the natural-production conditions of the Machine-Tractor Unit (MTU) was carried out taking into account the following parameters: farm sizes, soil texture, length of furrow, labor supply and technical equipment.

Using the obtained data as a base for a typical farm, the nominal tractive force of tractors and the composition of units were determined, ensuring the minimum aggregate costs for performing the whole range of works under the given conditions for all cultivated crops, taking in to account different technologies.

RESULTS AND DISCUSSION

In the system of machines, the basis for the classification of agricultural tractors is 11 traction classes from 0.1-8 with a nominal tractive force regulated by GOST 27021-86. Thus, the choice of tractors should be based on tractive forces and the scope of work. The second classification parameter is the power of tractor engine rated at ISO 14396 or operational according to GOST 18509, divided in a range from 3-400 kW of operating capacity by 12 classes (Esfahani *et al.*, 2013).

The justification of the traction classes of tractors includes the economic and mathematical efficiency modeling of various traction tractors on technological operations of moisture closure, pre-seeding treatment, seeding, chemical treatment, fallow tillage and autumn plowing.

The range of technical means for cultivating and harvesting agricultural crops is selected depending on the size of the cultivated area. In Kazakhstan, this area in agroformations varies from 25-20,000 ha and more.

When cultivating and harvesting agricultural crops for each technological operation, agronomical institutes determine the normative duration of mechanized works (term) which may vary in different years depending on the weather conditions (Shakhmayev and Yurkin, 1988). The production of the unit for term is:

$$W_a = 0.1 B v K_0 t_d T \quad (1)$$

Where:
B = Working width of the unit (m)
v = Average speed of the unit (km/h)
K_0 = Operating time utilization factor
t_d = Working hours (h)
T = Term for technological operation (days)

The total area F tilled by several units is:

$$F = N\ F_a \quad (2)$$

Where:
N = Number of units (ea)
F_a = Area processed by one unit (ha)

The number of units and the machine operators must be minimal. Below we will consider the questions on the justification of the tractor fleet range by the example of the Southern and Northern regions.

In the Southern region, due to the large number of small farms, a tractor of class 1.4 Belarus-80/82 is widely used for almost all technological operations.

As an example, let us consider plowing unit consisting of a tractor of class 1.4 (Belarus-80/82) and three-furrow plough PLN-3-35 with depth of 20, ..., 22 cm. Let us put the values in the equation 1 B = 1.05 m, V = 7 km/h, Fo = 0.8; T_d = 10 h, A = 18 days we get W_a = 105.8 ha.

This unit with depth of 20, ..., 22 cm on medium soils with a smooth relief can till 105 h. We have determined the dependence of the tractive force required by the plowing on the depth of 27, ..., 30 cm under the same conditions as before which is approximated by the linear model in the range of the change in the treated area from 70-300 ha with a confidence of 0.98 (Tahmassebpour, 2016):

$$P = 0.1247\ F + 12.5 \quad (3)$$

Where:
P = Tractive force of the tractor (kN)
F = Tillage area (ha)

At F = 70 ha, the tractive power required by the tractor is p = 21.2 kN, i.e., tractor must be at least class 2. Unit consisting of Belarus-1221 tractor and PLN-3-35 plough can be used.

For the tillage of an area F = 300 ha, tractor with tractive force of p = 49.9 kN is required, i.e., tractor must be class 5. We will apply a unit that includes class 5 tractor K-744P1 and PLN-8-35 or PNU-8-40 plough.

According to Eq. 1, we determine the production of seeding unit consisting of Belarus-80 tractor and C3-3.6 seeder during the seeding of winter cereals. By setting the value of B = 3.6 m; V = 10 km/h, K_e = 0.8; T_d = 10 h, A = 10 days we get W_a = 288 ha and during the seeding early grain crops where A = 4 days we get W_a = 115 ha.

Belarus-80/82 tractor with PLN-3-35 plough and SZ-3,6 drill can process the area when growing 100 or more hectares of grain.

In the Southern region, along with grain crops, soybeans, maize for grain and silage, sugar beet, vegetable crops are cultivated for the cultivation of which plowing should be carried out at the depth of 27, ..., 30 cm. For the plowing at this depth it is necessary to have caterpillar or wheeled tractor class 3 and for cultivating cotton with a two-tier plough at a depth of 40, ..., 42 cm a caterpillar tractor of class 4 T-4A type is required. For the performance of all other technological operations in the cultivation of these crops a tractor of class 1, 4 is required (Shakhmayev and Yurkin, 1988).

For the Southern region of the country, tractors of the following classes are necessary for the cultivation of crops at farms and agricultural enterprises: 1.4; 2; 3; 4; 5.

In Kazakhstan, 53, ..., 57% of the production is produced in the households on small plots where tractors of class 0.1 and 0.2 can be used. Small farms can use tractors of class 0.6 and 0.9.

The main tractor in most farms is a tractor class 1.4 (Belarus-80/82, etc.). Today, the purchase of agricultural tractors of class 2 (Belarus-1221) has increased.

Agriculture of the Northern region is conducted in conditions of risky agriculture with a seasonality of production and with limited availability of technical means. Therefore, timely and high-quality field work is possible only with high-quality preparation of existing equipment and its highly organized use in work.

In the context of the harsh continental climate of the Northern region, success largely depends on the timeliness and accuracy of the farmer's actions. The analysis of the work time shows that on average, timely seeding operations are carried out in 45% of farms or 30% of cultivated areas. Stretching the deadlines for performing work in the seeding period leads to significant crop losses. In these conditions, the timeliness of the work can be achieved only through the use of more productive equipment (Anonymous, 2012).

Therefore, the task of increasing productivity in the production of agricultural crops in the northern region becomes especially urgent where the main operations for their cultivation is currently performed by units with physically and morally outdated equipment in particular tractors. According to the program "Agrobusiness-2020" is provided for the increase of labor productivity in the agro-industrial complex by at least 4 times by 2020.

In Kazakhstan, work to justify the fleet of tractors for increasing labor productivity was carried out in the course of fulfilling the tasks of developing the systems of technologies and machines. Technical means were included in the system of technology and machines according to the results of optimization calculations and structure of the machine and tractor fleet. The expediency of switching to the use of crawler tractors of traction class 4-5 is justified. In the agriculture economy, there has been a steady tendency in reducing the number of staff. In these conditions, the tractor fleet, based on the application of tractors with traction class 4-5 does not solve the problem of increasing the productivity of labor.

Therefore, the problem of justifying a tractor fleet for agroformations of the main grain producers in Northern region of the Republic of Kazakhstan is urgent. This will help to increase labor productivity and perform work in optimal agro-technical terms with a shortage of machine operators, taking into account diversification of crop areas, resulting from the need of agricultural production which has a great importance at the stage of economic and social development of the Republic of Kazakhstan.

Purchasing a high-performance, energy-saturated tractors with engine power from 82-375 kW allowed for short agrotechnical terms cover up to 50% of the area for grain crops.

Updating the tractor fleet by simply replacing the tractors that are written off with similiar will not significantly increase the efficiency of work in agro-formations. Depending on the availability of machine operators and the yield of agricultural crops, it is necessary to use tractors that would ensure the performance of all work in economically expedient terms, i.e., the terms under which the minimum amount of aggregate costs for the operation of machinery and the cost of crop losses is ensured. The justification of the tractor fleet was carried out taking into account all the factors characterizing the natural and production conditions such as zonal technologies, provision with machine operators, cultivated crops, yield, size of farms, traction class and productivity of tractors.

To justify the tractor fleet, an economic-mathematical model was developed where as a criterion for effectiveness evaluation of agricultural machinery, the aggregate cost of financial resources, determined by the standard methodology from the following quation:

$$C_{t\beta} = C + C_{qp} + C_{wt} + C_{e} \rightarrow \min \qquad (4)$$

Where:

$C_{t\beta}$ = Total costs (tenge/ha)

C = Direct operating costs (tenge/ha)

C, C, C, costs that include the change in the quantity and quality of the product (loss); level of working conditions of maintenance personnel; negative impact on the environment (tenge/ha). The mathematical expression of the model has the following form:

$$Ct_{\beta} = \frac{B_{tr}\,(a_{tr} + r_{tr} + \mu)}{T_{tr}} + \frac{B_{m}\,(a_{m} + r_{m} + \mu)}{T_{m}} + \frac{B_{c}\,(a_{c} + r_{c} + \mu)}{T_{c}} + PbK_{w} + \rightarrow \min \qquad (5)$$

The individual components of the model are determined from the following dependencies:

$$Btr = a + cPH2Vw \qquad (6)$$

$$B\ (C \qquad (7)$$

$$B\ (C \qquad (8)$$

$$Lcr = Dw - DwlyKclCprod + Lcomp \qquad (9)$$

$$Dw = FopWshKwl \qquad (10)$$

$$W_{sh} = 0{,}1\ K_{ww}\ V_{s}\ K_{sh} \qquad (11)$$

$$L_{comp} = K_{comp}\ yC_{prod} \qquad (12)$$

$$F_{op} = \sum_{i=1}^{n} \frac{1000}{N_{opt}} \qquad (13)$$

$$C_{wc} = \frac{T_{ai}}{T_{aj}} \frac{(1 - l_{os})bp + \frac{C_{m}PK_{ts} + bT_{m}K_{wd}K_{ml}}{T_{mech}}}{W_{n}} \qquad (14)$$

$$C_{\beta} = N_{\beta p} \qquad (15)$$

Where:

B_{tr}, B_{m}, B_{c} = Respectively the book value of the tractor, machine, coupling (tenge)

a_{tr}, a_{m}, a_{c} = Coefficients of deductions for the renovation of the tractor, machines, couplings

r_{tr}, r_{m}, r_{c} = Coefficients of deductions for the repair and maintenance of the tractor, machines, coupling

μ = Bank credit for a loan or a deposit

T_{tr}, T_{m}, T_{c}, T_{op} = Annual usage of a tractor, machine, coupling, machine operator (h)

P = Number of maintenance personnel, persons

b = Payment for maintenance personnel, tenge/person (h)

K_w, K_{cl}, K_{comp}, K_w, K_r, K_{ww}, K_{sh}, K_{ts}, K_{wd}, K_{ml}, Coefficients: wages, accounting for crop losses per day for one hectare; losses from soil compaction; weather conditions; readiness of equipment; use of the working width of the unit; use of shift time; turnover of staff; loss of working days; material losses due to injuries.

P_t: price for 1 kg of fuel, tenge; q_h: fuel consumption per hour (kg); E_{op}: labor efficiency of the machine operator (tenge); W_{sh}: productivity per hour of shifting time (ha); C_{oth}: other costs (seeds, fertilizers, overhead costs, taxes, etc.) (tenge/ha); L_{cr}: cost of crop losses (tenge/ha); C_{wc}: costs that include the level of working conditions of the machine operator (tenge/ha); C_e: costs that include the negative impact on the environment (tenge/ha); Crr: costs for the training of one mechanic in a year, tenge; a, c: coefficients of equation; P_t: nominal tractive force of the tractor (kN); V_s: working speed (km/h); Cunit T, Cunit: unit cost of the machine and coupling (tenge/m); W_m, W_c: grasp width of the machine and the coupling (m); Lcr: cost of crop losses (tenge/ha); D: duration of work (days); Dw: duration of work without losses (days); D_{allow}: allowable duration of work (days); y: productivity (t/ha); L: cost of harvest losses from soil compaction (tenge/ha); C: Cost of products (tenge/t); F: load on the machine operator (ha); tsh: duration of the shift (h); n: number of simultaneous operations; N: number of machine operators engaged in the implementation of the ith operation, persons; Taj: actual loading of machinery on ith operation, h; Tj: annual actual loading of machinery (h); lo: Total composite index of occupational safety; Nep: norm of costs for environmental protection (tenge/kg); q: fuel consumption (kg/ha). Variable constraints: Nop≤Nop manag≤Dallow Vs≤V is not the negativity of variables. The partial coefficients of the use of shift times were determined from the results of previous observations of similar machines and equipment.

The development and implementation of the economic and mathematical model for the justification of the tractor fleet made it possible to establish that the dependence of the total costs on crop yields and the load on the machine operator is curvilinear with a pronounced extremum (Fig. 1-3).

It has been established that with an increase in the load on the tractor and the yield of agricultural crops, the minimum costs are shifted towards larger, more nominal forces of tractors. In addition with an equal load on the tractor when using no-till technology, it is possible to use tractors with a larger nominal tractive force than with soil protective technology. For example when tractor has load of 500 ha and yield 1 t/ha with no-till technology, tractors with a nominal tractive force of 50, ..., 80 kN (Fig. 1) can be used and for soil protective technology

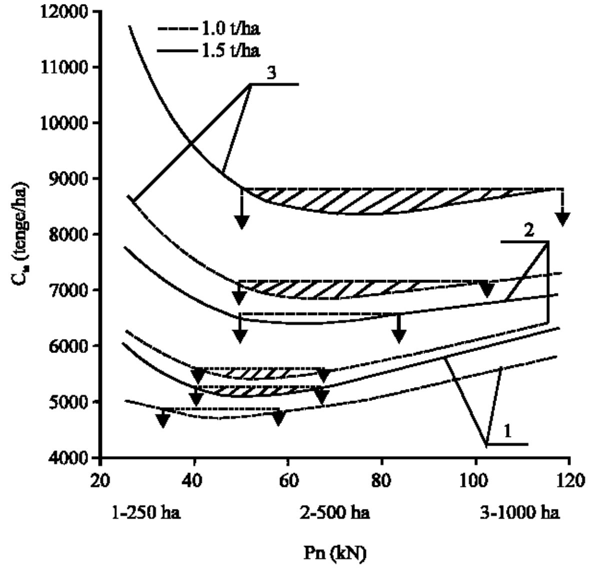

Fig. 1: Dependence of total costs from tractor load, crop yield and nominal tractor tractive force for no-till technology

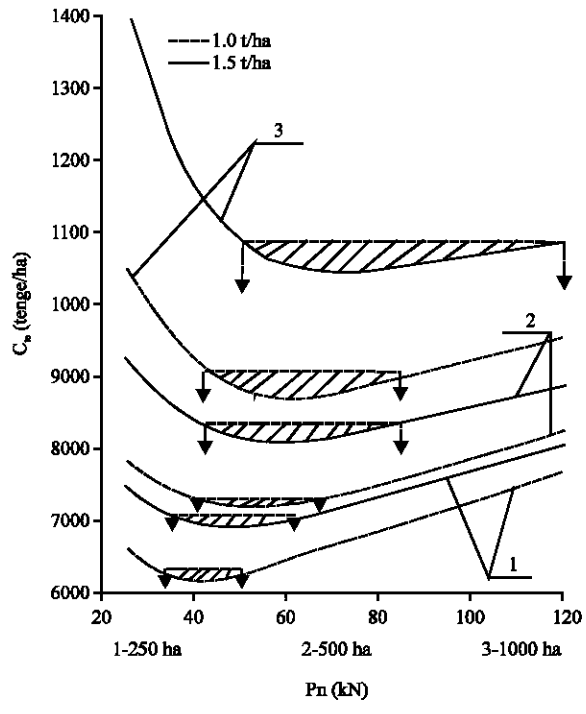

Fig. 2: Dependence of total costs from tractor load, crop yield and nominal tractor tractive force for minimum technology

50, ..., 70 kN (Fig. 3) with yield of 1.5 t/ha for no-till technology -60, ..., 100 kN and soil protective technology 50, ..., 80 kN.

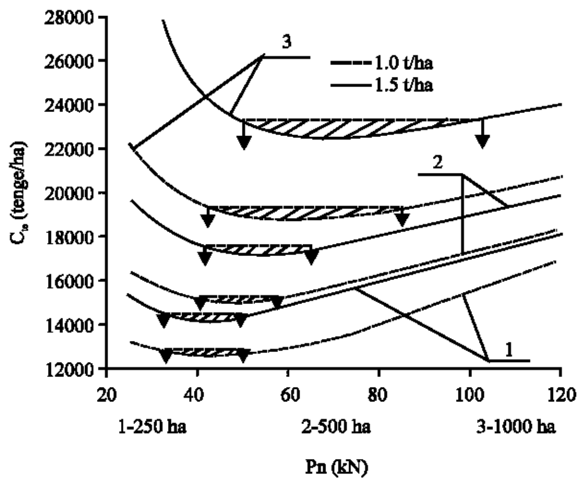

Fig. 3: Dependence of total costs from tractor load, crop yield and nominal tractor tractive force for soil protective technology

Analysis of Fig. 1-3 shows that with a small nominal tractive force of the tractors, the total costs increase due to an increase in the cost of losses (the left branch of the graphs) and with a large nominal tractive force, due to an increase in the cost of the tractors. As can be seen, the cost of increasing losses goes higher more intensively than the increase in the cost of tractors. At the same time, the use of tractors corresponding to the minimum amount of aggregate costs leads to their reduction to 7.5 thousand tenge/ha.

These calculations to determine the aggregate costs for tractors with different nominal tractive force, depending on crop yields and load on the tractor were performed for various agricultural crops (cereals, oilseeds, silage crops, etc.). Using the obtained calculation results as the initial ones, the aggregate costs were determined for the fulfillment of the whole set of works for all crops cultivated at the farm, taking into account different technologies. Based on the calculated data, depending on the load on the tractor and the yield of agricultural crops, the tractor fleet composition was determined which corresponds to the minimum of aggregate costs.

CONCLUSION

As a result of the conducted studies, it was established that tractors of the following classes are necessary for cultivation of agricultural crops in the Southern region at farms and agricultural enterprises: 1.4; 2; 3; 4 and 5. At the farms in small plots, tractors of class 0.1 and 0.2 can be used. At the small farms tractors of class 0.6 and 0.9 are applicable. In the Northern region where large-scale agro-formations predominate, tractors of class 1.4; 3; 4; 5; 6 and 8 are needed.

It is established that the application of no-till technology has the greatest impact on increasing labor productivity in field (for 2.5, ..., 3 times) compared to soil protective technology. Increasing the nominal tractive force of tractors from 40-50 to 60-80 kN and applying the minimum technology of cultivation provides an increase in labor productivity for 1.9, ..., 2 times and a decrease in total costs compared to soil protective technology.

The obtained results were used to justify prospective machines for agricultural work which increase the productivity of labor in the agroindustrial complex and prospects for the development of production capacities for the output of agricultural machinery in Kazakhstan.

REFERENCES

Anonymous, 2012. Report on the implementation of the program for the development of agro-industrial complex the Republic of Kazakhstan for 2013-2020. Ministry of Agriculture & Farmers Welfare, New Delhi, India.

Esfahani, M., M. Emami and H. Tajnesaei, 2013. The investigation of the relation between job involvement and organizational commitment. Manage. Sci. Lett., 3: 511-518.

Ghasemi, F., 2017. Clean energy efficiency of vernacular-traditional architectural indicators for the development of sustainable tourism. J. Sustainable Dev., 10: 250-261.

Shakhmayev, M.V. and V.I. Yurkin, 1988. Norms and Standards for Planning in the Branches of the Agroindustrial Complex. Agropromizdat, Moscow, Russia, Pages: 591.

Tahmassebpour, M., 2016. Performance evaluation and scalability of IP-based and heuristic-based job scheduling algorithm backup systems. Indian J. Sci. Technol., Vol. 9, 10.17485/ijst/2016/v9i26/97260.