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# Determining the Range of Combine Harvesters and Headers for Kazakhstan Regions

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**Abstract.** The fleet of combine harvesters in the Republic of Kazakhstan consists of 3-, 4-, 5- and 6-class harvesters, and 3- and 4- class harvesters make up for almost 82% of the fleet. According to the data provided by the Kazakhstan Ministry of Agriculture, 60% of grain harvesters have a lifespan of more than 10 years. (Research purpose) To determine the range of grain harvesters and headers for Kazakhstan regions in view of ongoing technical re-equipment. (Materials and methods) The range of grain harvesters should be determined according to the yield of harvested crops, the size of crop area on separate farms and in the region, the availability of machine operators as well as climatic conditions of the regions. (Results and discussions). The authors have analyzed the actual yield of grain crops in Kazakhstan regions, determined its possible expected level, and analyzed the number of machine operators required for available crop area, the number of small, medium and large-scale farms and climatic conditions during the harvest period in Kazakhstan regions. The efficiency of harvesters of different classes with headers of various operating width has been estimated taking into account the expected yield. Matching the obtained results to the yield data, organizational-and-economic and climatic conditions, and introducing appropriate limits, the authors have determined the range of grain harvesters for Kazakhstan regions. (Summary) It has been found that the harvesters of class 5, 6 and 4 are more effective under conditions of northern and central Kazakhstan regions provided they are equipped with wide-cut headers for direct harvesting. In southern, western and eastern Kazakhstan regions, where grain crops are cultivated on dry soils with an insufficient moisture content, combine harvesters of class 3 and 4 should be primarily used.
Keywords: combine harvesters, headers, range, regional conditions.

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The fleet of grain combine harvesters in the Republic of Kazakhstan is represented by combine harvesters of class 3-6. According to the Ministry of Agriculture of the Republic of Kazakhstan as of 01.01.2015, there are 44.3 thousand grain combine harvesters currently available in the republic, including 18.7 thousand (42%) Enisey 1200 and Yenisei-950 Ruslan, 15 thousand (34%) – SK- 5A Niva, 2,5 thousand (5,7%) – Vektor, 1 thousand (2,2%) - Don-1500. Combines produced by far abroad manufacturers – 4.6 thousand available in 10 different brands. Thus, almost 82% of the fleet consists of combine harvesters of class 3 and 4. The fleet of grain harvesting equipment is mainly represented by combines coming from the following countries: Russian Federation (Rostselkhozmash, Krasnoyarsk Combine Plant, Promtraktor); the Republic of Belarus (Gomselmash, Agropromtehnika); the Republic of Kazakhstan (Agromashholding); USA (*JohnDeere*, *Challenger*, *MasseyFerquson*, *Case*, *NewHolland*), Germany (*Class*, *DeutzFahr*, *Fend*); Italy (*Laverda*); Finland (*Sampo*). According to the Kazakhstan Ministry of Agriculture, 60% of combine harvesters have a service life of more than 10 years, so the issue of technical re-equipment of the fleet of grain combine harvesters is very relevant. As organizational and economic conditions in the regions of Kazakhstan have changed significantly in recent years due to an increase in the share of peasant farms and the growing demand for machine operators, this issue cannot be solved by automatically replacing old harvesters with new ones of the same class.

**THE PURPOSE OF THE PRESENT RESEARCH** is to determine

the type of combine harvesters and headers in Kazakhstan regions in connection with the ongoing technical re-equipment.

**Materials and methods.** The determination of the range of combine harvester classes is made taking into account the yield amount of the harvested crops, the acreage of farms and in the region, the availability of machine operators, and weather conditions in separate regions [1-5]. When determining the range of combine harvesters, we have proceeded from the following methodological assumptions:

- in regions with high yield and a shortage of machine operators, higher-class combine harvesters should be used;
- the reduction in the crop area in farms leads to a reduction in seasonal load on combines and, as a result, a decrease in the class of a combine harvester used;
- in regions with high probability of precipitation, it is advisable to use combine harvesters with higher productivity to avoid produce losses due to unfavorable weather conditions;
- in regions with an average amount of yield, the full-load performance of a high-capacity combine harvester can be ensured by the use of wide-cut reapers and cutting headers, as well as for separate harvesting with picking up double swaths.

The productivity of a combine harvester of direct action is basically determined as follows: the width of the harvesting unit and the combine travel speed. The combine travel speed is subject to the full load of its thresher, was determined basing on the condition:

$$V = \frac{36}{BY} q_з \le V_д, \quad (1)$$

where $V$ is the combine travel speed, km/h;

$V_d$ – allowable travel speed of combine harvester of class 3-6, km/h;

$q_з$ – zonal throughput capacity of grain mass at the grain weight-to-straw ratio 1:1.2, kg/s;

$B$ – header width, m;

$Y$ – yield of grain mass, t/ha:

The amount of threshing unit load for zonal grain yield has been determined using the formula:

$$C_з = \frac{B}{q_з}\frac{V}{36} Y_з (1 + a_ф) 100\%, \quad (2)$$

where $C_з$ is the threshing unit load;

$a_ф$ is the straw content of grain mass (the straw-to-grain mass ratio), $a_ф$ = 1.2;

$Y_з$ – grain yield in zonal conditions, t/ha.

The cutting width of headers needed to increase the loading of grain harvesters by the throughput capacity for zonal grain yield has been determined from the condition:

$$B = \frac{36 q_з}{(1 + a_ф) V_d Y_з} \le [B], \quad (3)$$

where $[B]$ is the maximum possible cutting width of headers and cutting reapers to be attached with combine harvesters of class 3-6.

**Results and discussion.** Basing on the analysis of the yield level, organizational-economic and weather conditions in the regions of the Republic of Kazakhstan, we have determined a promising range of combine harvesters and headers by their classes for grain harvesting in Kazakhstan.

Combine harvesters are classified according to the throughput capacity (kg/s) as follows [6, 7]:

- Class 1 with a throughput capacity of 0.5-1.5 kg/s - selection combine harvesters;
- Class 2 with a throughput capacity of 2.5-3 kg/s, for small farms with an area of 70-100 hectares;
- Class 3 with a throughput capacity of 5.5-6 kg/s, for operating in fields with a yield of less than 25 c/ha;
- Class 4 with a throughput capacity of 7-8 kg/s, for operating in fields with a yield of 25-40 c/ha;
- Class 5 with a throughput capacity of 9-10 kg/s, for operating in fields with a yield of 40-55 c/ha;
- Class 6 with a throughput capacity of 11-12 kg/s, for operating in fields with a yield of 50-60 c/ha;
- Class 7 with a throughput capacity of 12-14 kg/s, for operating in fields with a yield of 60-100 c/ha.

Table 1

**Wheat yield in separate regions of the Republic of Kazakhstan**

| Region | Average wheat yield, c/ha | | Maximum wheat yield, c/ha | |
|---|---|---|---|---|
| | actual | potential | actual | potential |
| Southern | 16,5 | 20,6 | 20,9 | 25,0 |
| Eastern | 12,3 | 15,4 | 14,2 | 18,0 |
| Western | 5,6 | 7,0 | 8,4 | 10,0 |
| Northern | 10,6 | 13,5 | 15,3 | 19,0 |
| Central | 10,5 | 13,1 | 11,0 | 14,0 |

*Table 1* shows the wheat yield differentiated by Kazakhstan regions, and the average wheat yield obtained over a period of five years (2009-2014) for the country is 11.5 c/ha.

The average and maximum wheat yield obtained over a period of five years is the largest in the southern region, which is mainly due to the presence of irrigated land there, where winter wheat is cultivated and the yield is 40 c/ha and higher. However, the cultivation of winter wheat on irrigated land has been declining in the southern region in recent years, as priorities have been given to other crops. It should be noted that grain combine harvesters are used to harvest rice in the republic, the yield of which in yielding years is 45 c/ha or higher, and corn to be used for grain seed production, the average yield of which is 45 c/ha, and the maximum yield is 70 c/ha. To harvest these crops, high capacity

combines of class 5 and 6 are required. According to the Kazakhstan Ministry of Agriculture, due to worn-out equipment, the loss of yield is currently estimated at 25%, as minimum. The range of combine harvesters can be determined taking into account a possibility of obtaining expected yields without planning for these losses.

Table 2

CROP AREAS IN SEPARATE REGIONS OF THE REPUBLIC OF KAZAKHSTAN

| Region | Crop area | |
|---|---|---|
| | thousand ha | % |
| Southern | 2528 | 11,6 |
| Eastern | 1358 | 6,3 |
| Western | 1105 | 5,1 |
| Northern | 15521 | 71,8 |
| Central | 1119 | 5,2 |

*Table 2* shows the size of crop areas in separate regions of the Republic of Kazakhstan.

The largest share of crop areas belongs to the northern region. This region is characterized by the presence of farms of various categories (family farms, medium and large farm enterprises) with crop areas of 300-3000 ha; 3000-10000; and more than 10000 hectares, respectively. Moreover, large and medium-size farms in the region account for more than 20% and operate 71% of the crop area. The beginning of the harvest period (the third decade of August) is usually dry, but in September, as a rule, it begins to rain.

In the eastern and southern regions there is an overwhelming majority (more than 90%) of small farms with a crop area amounting to 25-500 hectares. The sizes of agricultural enterprises of these regions range from 130 to 7000 hectares [8]. In the central region, as well as in the north, large and medium-size agricultural enterprises are more typical, and in the western part, small farms account for the largest part (over 80%). Autumn in the southern, central and western regions is usually dry.

The structure of the combine harvester fleet in the republic is comprised of combines of class 3 – 77.6%; class 4 – 11.2%; class 5 – 7,8%, and class 6 – 3,4%. However, the distribution by regions is not equal. So, in the southern region, combine harvesters of class 3 make up for 90.6%; class 4 – 4.4%; class 5 – 3%; class 6 – 2%. In the northern region, combines of class 3 make up for 70.7%, class 4 – 14.6%; class 5 – 8.2%, class 6 – 5.8%.

Thus, in the northern region with the largest grain areas of relatively high yields, the share of high-performance combines of class 4, 5 and 6 is about 30%, while in the southern region – 9.4%, and in the whole in the republic – 22.4%. The increase in the share of high-class combines in the northern region is due to the limited periods of favorable weather in the autumn period and the strive of agricultural producers to maximize the productivity of machines in the harvesting process accompanied by a shortage of machine operators.

Our task is to determine the productivity and the degree of loading of threshing unit of different combine classes with different grain yields. The recommended travel speed of a direct combining harvester is 4-8 km/h [9, 10]. However, according to the test results of combine harvesters of class 3-6 in the KazNIIMESKH in the conditions of Kazakhstan regions at low grain yields for 3-4 class harvesters $V_д \leq 8$ km/h, for 5 class combines $V_д \leq 9$ km/h and for 6 class combine harvesters – $V_д \leq 10$ km/h.

Combine harvesters of class 3-4 are not fully loaded in harvesting at yields of 12 c/ha (*Table 3*). To increase their loading, it is necessary to use headers with a larger operating width. However, wide-cutting headers can be effectively used in steppe areas, but in foothill areas their use disrupts the movement stability of the harvester. The use of an *ACROS-530* 5-class harvester with a harvesting width (B) of 11 m for grain harvesting at yields of 12, 15 and 17 c/ha in the northern region of the Republic makes it possible to increase the actual feed (and productivity) by 1.7-2.5 times, as compared with 3-class harvesters. At the same time, the average load of the threshing unit in 5-class harvester is 64% at a yield of 12 c/ha, 80% at a yield of 15 c/ha, and 80% at a yield of 17 c/ha. In the first case, the combine harvester is underloaded by about a third, and in the latter case it is loaded almost completely. With the use of combine harvesters of 6 class with a cutting width of 12 m, the specific (per hectare) performance is even higher, as these combines operate at a yield of 12-17 c/ha with permissible losses at speeds of up to 10 km/h. Thus, the use of 6-class harvesters with wide-cutting headers can raise specific (per hectare) performance in grain harvesting at a yield of 12-17 c/ha as compared with 3- and 4-class harvesters.

The conformity of the harvesting width to the type of combine harvesters has been determined by Formula 3. At present, the harvesting width of direct combining headers attached to combine harvesters of class 3 is 5-6 m; class 4 – 6-9 m; class 5 – 6-12 m; and class 6 –- 9-12 m. To increase the load of the thresher and the harvesting efficiency of the combine harvesters of class 3, 4, 5 and 6, the harvesting width of a direct combining harvester must be increased to the upper limits in all Kazakhstan regions, except for foothill areas and watered fields.

The performed analysis, as well as the experience of advanced farms in the northern region, which is the main grain production area, has made it possible to

Table 3

**PERFORMANCE OF COMBINE HARVESTERS PER 1 HOUR OF OPERATION DEPENDING ON WORK LOAD IN HARVESTING GRAIN CROPS OF DIFFERENT YIELD LEVEL**

| | Harvester class and make | Initial conditions | | | | | |
|---|---|---|---|---|---|---|---|
| | | Grain yield, ql/ha | Thresher capacity, kg/s | Working width, m | Velocity, km/h | Actual feeding rate, kg/s | Loading rate, % |
| *3 class* | SK-5M-1 "Niva" | 12 | 5,5 | 6 | 8 | 4,8 | 64 |
| | SK-5ME-1 "Niva-Eff." | 15 | 5,5 | 6 | 8 | 4,8 | 80 |
| | | 17 | 5,5 | 5 | 8 | 4,0 | 91 |
| | | 20 | 5,5 | 5 | 7 | 3,5 | 93 |
| | Enisey-1200-1NM | 12 | 6,3 | 7 | 8 | 5,6 | 65 |
| | | 15 | 6,3 | 7 | 8 | 5,6 | 81 |
| *4 class* | RSM-101 "Vektor" | 12 | 8 | 7 | 8 | 5,6 | 51 |
| | | 15 | 8 | 7 | 8 | 5,6 | 64 |
| | | 17 | 8 | 7 | 8 | 5,6 | 73 |
| | Palesse GS 07 (KZS-7) | 12 | 8 | 9 | 8 | 7,2 | 66 |
| | | 15 | 8 | 9 | 8 | 7,2 | 83 |
| | | 17 | 8 | 9 | 8 | 7,2 | 93 |
| *5 class* | ACROS-530 | 12 | 10 | 11 | 8 | 8,8 | 65 |
| | | 15 | 10 | 11 | 8 | 8,8 | 81 |
| | | 17 | 10 | 11 | 8 | 8,8 | 83 |
| | | 40 | 10 | 6 | 6,1 | 3,7 | 90 |
| *6 class* | Palesse GS 12 (KZS-1218) | 12 | 12 | 12 | 10 | 12,0 | 63 |
| | | 15 | 12 | 12 | 10 | 12,0 | 92 |
| | | 17 | 12 | 12 | 9 | 10,8 | 93 |
| | | 40 | 12 | 6 | 8 | 4,8 | 88 |

identify a promising type of combine harvesters in the Republic: combine harvesters of class 4, 5 and 6 (*Table 4*).

Table 4

**PERSPECTIVE RANGE OF GRAIN COMBINE HARVESTERS**

| Combine harvester class | Regions | | | | | For Kazakhstan as a whole |
|---|---|---|---|---|---|---|
| | northern | southern | central | eastern | western | |
| 3 | – | + | + | + | + | + |
| 4 | + | + | + | + | + | + |
| 5 | + | + | + | + | + | + |
| 6 | + | + | + | – | – | + |

In the southern region, where winter wheat, rice, and maize are cultivated on irrigated lands to obtain high-yield grain, combine harvesters of class 5 and 6 will be effectively used (*Table 4*).

However, due to a large share of small farms, the combine harvester range will be basically made up of 3-class harvesters. In the western and eastern regions of the Republic, where grain crops are cultivated on rainfed lands with moisture deficiency, it is preferable to use 3- and 4-class harvesters. This is due to a large share of small farms, as well as low grain yields (the western region). Combine harvesters of a higher class are advisable to apply in the central and western regions in large and medium-sized agricultural enterprises that are characterized with a shortage of machine operators, and in the eastern region that feature high grain yields. Thus, in the northern region, where grain crop yields are higher and the share of large and medium-size farms is large with a pronounced shortage of machine operators, combine harvesters of class 5 and 6 are the most effective solution, provided they are equipped with wide-cut headers for direct and separate harvesting. On smaller farms, 4-class combines can also be used if equipped with wide-cut headers. Calculations have shown that when switching to a promising type of combine harvesters and headers and operating the required number of these machines, it is possible to ensure the harvesting operations to be done in the required periods.

## CONCLUSIONS:

1. It has been established that in the conditions of the main grain producing northern and central regions of Kazakhstan, characterized by a significant share of large and medium-size farms with a pronounced shortage of machine operators, combine harvesters of class 5, 6 and 4 are the most effective solutions if they are equipped with wide-cut headers for direct and separate harvesting.

2. In the southern region, due to a large share of small farms, the combine harvester range will be made up of 3-class harvesters. Harvesters of class 5 and 6 can be used in areas, where winter wheat, rice, and corn for grain with high yields are cultivated in irrigated fields.

3. In the western and eastern regions of the Republic, where grain crops are cultivated on rainfed lands with a moisture deficit, 3- and 4-class harvesters are predominantly used. This is due to a large share of small farms and low grain yields (the western region).

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