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Reliability monitoring of grain harvester

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Abstract. This paper is focused on evaluation of operating reliability of grain harvesters. The aim of research is to improve the efficiency of combine harvesters by calculations which indicate a minimum annual performance and try to move in profit despite the high annual costs. Methods of paper containing all conditions of monitoring and evaluating of responsibility of grain harvesters. Those harvesters worked in real operating conditions. During three years of monitoring all important and other facilities and conditions of watching were recorded. After accumulation of information, their following working was set out according to the given literary sources and according to the own discretion based on experience during monitoring. The last part is focused on evaluating results and personal proposals how to make individual components work more effective. The most important results was recorded in case of turning point calculation where in years 2013, 2014 and 2015 at values 157.93, 156.19 and 166.86 ha year^{-1}, respectively. However, real annual performance was recorded at values 760.5, 604.6 and 905.5 ha year^{-1}. Thus, in all years of observation the grain harvester finished in profits.

Key words: harvester, reliability, performance, cost, turning point.

INTRODUCTION

Agriculture is, certainly, one of the most important industries in the world. It is mainly from two aspects. The first is a fundamental aspect of food security for the population of different countries. The second aspect, which is not less important, is a forage production for livestock production and raw materials for other industries (de Toro et al., 2012; Findura et al., 2013, Nozdrovický et al., 2013).

In Slovakia, crop production has still a large enough presence in the cultivation of cereals. Grain harvest is the most difficult operation in agriculture. The harvest belongs to the activities where you can clearly see the result of all seasonal efforts (Žitňák et al., 2014; Žitňák et al., 2015). Grain harvesters are used during grain harvest. In the past, harvesters were part of all cooperatives, but today the trend shifted to organizations that provide harvest work and relieve the other organizations from the costly operation of grain harvesters. Whereas any one of grain harvest has different conditions (Lee et al., 2016), a great attention must be paid to precise adjust of different parts and components of grain harvester. When errors occur, unwanted harvesting losses certainly displease every farmer (Korenko et al., 2012a; Korenko et al., 2012b; Vladut et al., 2012; Korenko et al., 2015).

Nowadays in modern agricultural machinery, including grain harvesters, it is very important to use them effectively with the highest emphasis on performance and quality of work. The recent grain harvesters are equipped with modern features that provide much higher performance than in the past (Craessaerts et al., 2010; Hanna & Jarboe, 2011; Beloev et al., 2012; Singh et al., 2012; Bujna & Beloev, 2015).

The role of this paper is to monitor John Deere 9660 WTS harvester. The harvester is the property of GoldAgro, Ltd. which is mainly focused on the provision of harvesting services. Grain harvesters provide services throughout Slovakia, Czech Republic and a little of the services performed are in the border areas of Austria and Hungary. We conducted monitoring for the years of 2013, 2014, 2015. Calculating turning points we will ascertain whether the grain harvesters move in loss or profit (Prístavka et al., 2013; Prístavka & Bujna, 2013; Beneš et al., 2014; Prístavka & Bujna, 2014; Mašek et al., 2015).

MATERIALS AND METHODS

The used data were collected during the years of 2013, 2014 and 2015 and they concerned mainly at the cost of the machine, the cost of amortization, capitalization of capital, insurance, bank interest, garaging, repairs and maintenance costs and fuel.

The calculation of the costs harvesters operation

The annual operating cost of the machine can be expressed as:

$$rN_sp = rN_sk + rN_sv \tag{1}$$

where: rN_sp – operating costs of the machine, € year^{-1}; rN_sk – constant costs of the machine, € year^{-1}; rN_sv – variable costs of the machine, € year^{-1}.

Constant costs of the machine can be expressed as:

$$rN_sk = rN_sa + rN_sz + rN_sdmv + rN_szp + rN_su + rN_svp + rN_sg \tag{2}$$

where: rN_sa – annual cost of the machine amortization, € year^{-1}; rN_sz – annual cost of the machine to interest on capital, € year^{-1}; rN_sdmv – annual cost of the machine to the motor vehicle tax, € year^{-1}; rN_szp – annual cost of the machine to insurance statutory, € year^{-1}; rN_su – annual cost of the machine to bank interest, € year^{-1}; rN_svp – annual cost of the machine to optional insurance, € year^{-1}; rN_sg – annual cost of the machine to garaging, € year^{-1}.

Variable annual costs can be expressed as:

$$rN_sv = rN_so + rN_se + rN_szp \tag{3}$$

where: rN_so – the annual cost of the machine to repair and maintenance, € year^{-1}; rN_se – the annual cost of the machine to energy, including fuel and lubricants, € year^{-1}; rN_szp – the annual cost of live work, including contributions, € year^{-1}.

The costs of machine amortization

The annual costs of machine amortization can be expressed as:

$$rN_sa = \frac{CO_s \,.\, a_s}{100};\ (€\ \text{year}^{-1}) \tag{4}$$

where: CO_s – cost of machine; €; a_s – depreciation rate for machinery, %.

Unit costs of machine amortization can be expressed as:

$$jN_s a = \frac{rN_s a}{rW_s}; \ (€\ ha^{-1}) \tag{5}$$

where: rW_s – annual machine performance, ha year^{-1}.

The costs of interest on capital

The annual costs of interest on capital can be expressed as:

$$rN_s z = \frac{(CO_s + CZ_s)}{2} . \frac{z}{100} . KZ; \ (€\ year^{-1}) \tag{6}$$

where: CO_s – costs of machine, €; CZ_s – net value of the machine, €; z – interest on own capital, %; KZ – mathematical correction calculating the remuneration.
while:

$$KZ = 0{,}8742 + 0{,}0013 . \left(\frac{VK_s}{CO_s} . 100\right); \tag{7}$$

Unit costs of interest on capital can be expressed as:

$$jN_s z = \frac{rN_s z}{rW_s}; \ (€\ ha^{-1}) \tag{8}$$

where: rW_s – annual machine performance, ha year^{-1}.

The cost of vehicle tax

From the 1st of January 2005 the road taxi s replaced by the so-called motor vehicle tax. Motor vehicle tax are imposed (in accordance with the provisions of Law no. 582/2004 on local taxes and local fees for municipal waste and minor construction waste and the provisions of Law no. 583/2004 on budget rules of local governments and amending certain laws) by independently higher territorial units (HTU). This regulation include the amount of tax scales.

Pursuant to EC-Regulation. 582/2004 and generally binding regulations of the Higher Territorial Units (HTU), tax is not applied to the agricultural working machine.

The costs of compulsory liability insurance for damage caused by motor vehicles

The annual cost of liability insurance can be expressed as:

$$rN_s zp = rS_s zp; \ (€\ year^{-1}) \tag{9}$$

where: $rN_s zp$ – annual rate of liability insurance for damage caused by motor vehicles for the machine, € year^{-1}.

Unit cost of liability insurance can be expressed as:

$$jN_s zp = \frac{rN_s zp}{rW_s}; \ (€\ ha^{-1}) \tag{10}$$

where: rWs – annual machine performance, ha year^{-1}.

Costs associated with the use of external sources of capital

Annual cost of bank loan can be expressed as:

$$rN_s u = \frac{SBU_s}{t_s} - \frac{I_s}{t_s};\ (€\ year^{-1}) \quad (11)$$

where: SBU_s – total payment of a bank loan for the acquisition of machinery, including interest, €; I_s – principal, €; t_s – operation time of machine, years.

Unit costs of a bank loan can be expressed:

$$jN_s u = \frac{rN_s u}{rW_s};\ (€\ ha^{-1}) \quad (12)$$

where: rWs – annual machine performance, ha $year^{-1}$.

The costs of optional insurance

The annual cost of machine optional insurance can be expressed as:

$$rN_s vp = \frac{CO_s\ .\ p}{100};\ (€\ year^{-1}) \quad (13)$$

where: CO_s – cost of machine, €; p – negotiated insurance rates, %.

Unit costs for an optional insurance of the machine can be expressed as:

$$jN_s vp = \frac{rN_s vp}{rW_s};\ (€\ ha^{-1}) \quad (14)$$

where: rW_s – annual machine performance, ha $year^{-1}$.

Costs of garaging

The annual cost of garaging can be expressed as:

$$rN_s g = (l_s + 1).(b_s + 1).sgp_s;\ (€\ year^{-1}) \quad (15)$$

where: l_s – machine length, m; b_s – machine width, m; sgp_s – annual fee for the use of garage area, € m^{-2} $year^{-1}$.

Unit costs for garaging can be expressed as:

$$jN_s g = \frac{rN_s g}{rW_s};\ (€\ ha^{-1}) \quad (16)$$

Costs of repairs and maintenance

Mid-unit cost of repairs and maintenance can be expressed as:

$$j_{str}N_s o = \frac{r_{str}\ N_s o}{rWn_s};\ (€\ ha^{-1}) \quad (17)$$

where: rWn_s – annual normative performance of the machine, ha $year^{-1}$.

Qualified estimate of the cost for repairs and maintenance

A simple estimate of the annual cost of the machine for repair and maintenance can be expressed as:

$$rN_s o = rN_s a.k_o;\ (€\ year^{-1}) \quad (18)$$

where: rN_sa – annual cost of amortization with linear way of depreciation, € year^{-1}; k_o – coefficient of repairs.

Standard method for calculating annual costs of the machine for repair and maintenance can be expressed as:

$$rN_so = rN_sa_{10}.k_o.\frac{rWn_s}{rW_{s10}};\ (€\ year^{-1}) \tag{19}$$

where: rN_sa_{10} – annual cost of amortization at 10 years of operation in, € year^{-1}; k_o – coefficient of repairs; rW_{s10} – mid-annual machine utilization at 10 years of operation, ha year^{-1}; rWn_s – standard annual machine utilization, ha year^{-1}.

The unit estimate of the cost for repairs and maintenance can be expressed as:

$$jN_so = \frac{rN_so}{rWn_s};\ (€\ ha^{-1}) \tag{20}$$

while a coefficient of repairs is given by the ratio and can be expressed as:

$$k_o = \frac{rN_so}{rN_sa}; \tag{21}$$

where: rN_so – annual cost of repairs at the time of use, € year^{-1}; rWn_s – annual machine performance at the time of use, € year^{-1}; rN_sa – annual cost of the machine for amortization, € year^{-1}.

Costs of machine for energy

The annual costs of the machine for energy without VAT can be expressed as:

$$rN_se = Q.\left(\frac{Ce}{1+\frac{DPH_{UP}}{100}}\right).rW_s.\left(1+\frac{PSM}{100}\right);\ (€\ year^{-1}) \tag{22}$$

where: Q – energy consumption (fuel), l ha^{-1}; Ce – cost of energy (fuel) including VAT, € l^{-1}; DPH_{UP} – VAT rate for hydrocarbon fuels, %; rW_s – machine performance, ha year^{-1}; PSM – premise of lubricants consumption, %.

Unit costs of the machine for energy can be expressed as:

$$jN_se = \frac{rN_se}{rW_s};\ (€\ ha^{-1}) \tag{23}$$

The cost of living labour

Annual costs of living labour can be expressed as:

$$rN_{zp} = \left(S_{hod} + \frac{S_{hod}.\sum ODV}{100}\right).RP + CN.RP;\ (€\ year^{-1}) \tag{24}$$

where: S_{hod} – hourly rate, € h^{-1}; ΣODV– sum of contributions pertaining S_{hod}, %; RP – scope of work, h year^{-1}; CN – travel expenses, € h^{-1}.

Unit costs for living labour can be expressed as:

$$jN_{zp} = \frac{rN_{zp}}{rW_s};\ (€\ ha^{-1}) \quad (25)$$

where: rW_s – annual performance of the machine, ha year^{-1}.

Pricing mechanized work

The price of mechanized work can be expressed as:

$$CMP_s = jN_s p. \left(1 + \frac{MZ}{100}\right);\ (€\ ha^{-1}) \quad (26)$$

where: CMPs – price of mechanized work of the machine, € ha^{-1}; MZ – profit margin, %.

RESULTS AND DISCUSSION

John Deere WTS 9660 harvester with a daily output of 30–40 ha, cutting table with a length of 6.6 meters, adapters for sunflower and maize of Oros brand with 6 rows with a daily output of 15 to 20 hectares, built in 2006, power of 340 PS, 4 x 4, hill master engine capacity 8.13 liters, number of cylinders 6, container volume 9,000 litters, 700 litters fuel tank. John Deere harvester with the year of manufacture 2006 when it was also purchased by the GoldAgro organization cost € 215,760 (Table 1). The full price was paid in 2009 and economically depreciated in the same year. Own funds accounted for the amount of € 75,000 and € 140,760 was a bank loan. Each of costs is shown in Table 1–4.

Table 1. Operation parameters of John Deere WTS 9660

Characteristics of John Deere WTS 9660 operation parameters				
Years		2013	2014	2015
Cost of the machine, €	CO_s	215,760	215,760	215,760
Own funds, €	VK_s	140,760	140,760	140,760
Bank loan, €	BU_s	-	-	-
Plan. net machine price, €	ZC_s	0	0	0
Depreciation, years		-	-	-
Rate of remuneration on current accounts, %	Z	5	5	5
Real annual performance, ha year^{-1}	rW_s	716.50	604.60	905.50
Real hourly performance, ha h^{-1}	hW_s	2.2	2.2	2.6
Normative annual performance, ha year^{-1}	rW_sn	1,000	1,000	1,000
Normative hourly performance, ha h^{-1}	hW_sn	2.5	2.5	2.5
Real fuel consumption, l ha^{-1}	Q_s	17	16	17
Normative fuel consumption, l ha^{-1}	Q_sn	14 – 16	14 – 16	14 – 16
Diesel price incl. VAT, € l^{-1}	Ce	1.314	1.409	1.371
Premise of lubricants consumption, %	PSM	18	33	41
Engine power, kW	P_m	249	249	249
Machine width, mm	b_s	3,250	3,250	3,250
Machine length, mm	l_s	8,900	8,900	8,900

Table 2. Table of fixed costs in annual terms for John Deere 9660 WTS in 2013, 2014, 2015

Item costs	Units	2013	2014	2015
Costs of amortization	€ year^{-1}	-	-	-
Costs of interest on capital	€ year^{-1}	5,124.30	5,124.30	5,124.30
Costs of vehicle tax	€ year^{-1}	-	-	-
Costs of insurance for damage	€ year^{-1}	82	82	82
Costs of ban interests	€ year^{-1}	-	-	-
Costs of optional insurance	€ year^{-1}	2, 157.60	2,157.60	2,157.60
Costs of garaging	€ year^{-1}	134.64	134.64	134.64
Total	€ year^{-1}	7,498.54	7,498.54	7,498.54

Table 3. Table of variable costs in annual terms for John Deere 9660 WTS in 2013, 2014, 2015

Item costs	Units	2013	2014	2015
Costs of repairs and maintenance	€ year^{-1}	3,058.00	3,000.50	4,156.00
Costs of fuel	€ year^{-1}	15,738.42	15,106.69	24,797.77
Costs of live labour	€ year^{-1}	2,224.47	1,877.69	2,811.25
Total	€ year^{-1}	21,020.89	19,984.88	31,765.02

Table 4. Table of total costs in annual terms for John Deere WTS 9660 for the years of 2013, 2014, 2015

Item costs	Units	2013	2014	2015
Total annual costs	€ years^{-1}	28,519.43	27,483.42	39,263.56
Total annual revenues	€ years^{-1}	54,019.42	49,026.84	60,693.17
Variable units costs	€ ha^{-1}	29.32	33.04	35.06

John Deere WTS 9660 (2013)

John Deere WTS 9660 (in 2013) had a performance of 716.50 ha year^{-1}, and we calculated the defined turning point (Fig. 1; Table 6) at a value of 157.93 ha year^{-1} (Fig 2). Thus, in 2013 the grain harvester finished in profits (Table 5).

Table 5. Determination of the minimum annual performance of John Deere 9660 WTS in 2013

John	2013			
Deere	Labour price, € ha^{-1}	rN_sk, € year^{-1}	jN_sp, € ha^{-1}	rW_{min}, ha year^{-1}
WTS 9660	76.80	7 498.54	29.32	157.93

Table 6. Data table for calculating the turning point of John Deere 9660 WTS in 2013

rW_s, ha year^{-1}	rN_sk, € year^{-1}	rN_sv, € year^{-1}	rN_sp, € year^{-1}	rVs, € year^{-1}
0	7,498.51	0	7,498.51	0
157.93	7,498.51	4,630.50	12,129.01	12,129.01
400	7,498.51	11,728	19,226.51	30,000
800	7,498.51	23,456	30,954.51	60,000
1,200	7,498.51	35,184	42,682.51	90,000
1,600	7,498.51	46,912	54,410.51	120,000
2,000	7,498.51	58,640	66,138.51	150,000
2,400	7,498.51	70,368	77,866.51	180,000
2,800	7,498.51	82,096	89,594.51	210,000
3,200	7,498.51	93,824	101,322.51	240,000

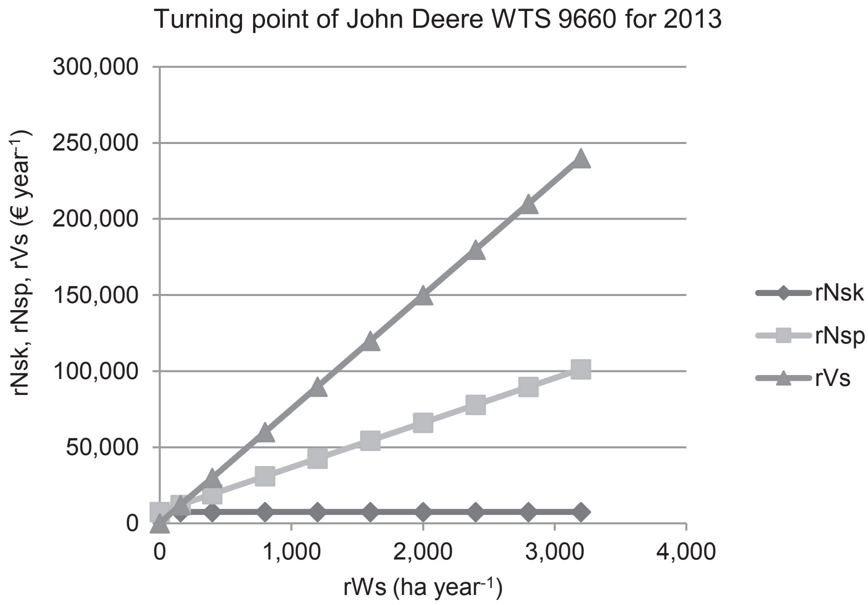

Figure 1. Graph of John Deere WTS 9660 turning point for 2013.

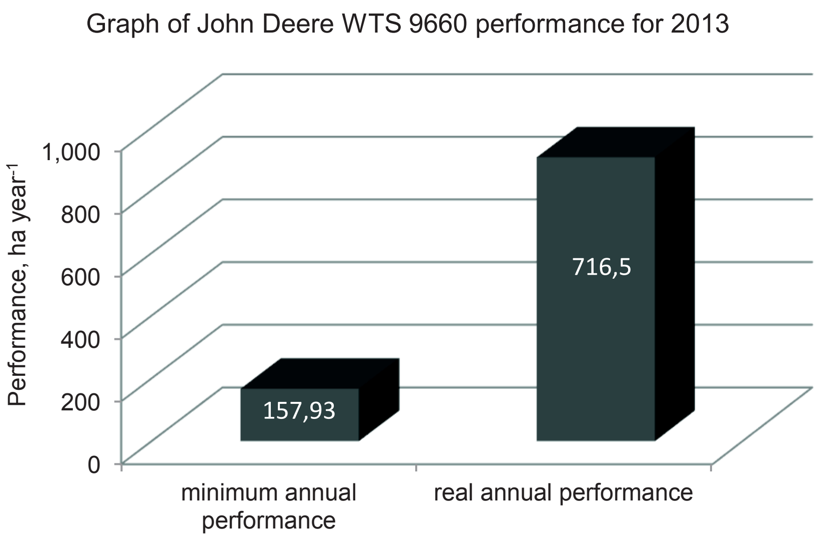

Figure 2. Graph of John Deere WTS 9660 performance for 2013.

John Deere WTS 9660 (2014)

John Deere 9660 WTS 2014 grain harvester had a performance of 604.60 ha $year^{-1}$, and we calculated the defined turning point (Fig. 3; Table 8) at a value of 156.19 ha $year^{-1}$ (Fig. 4). Thus, in 2014 the grain harvester finished in profit (Table 7).

Table 7. Determination of the minimum annual performance of John Deere 9660 WTS 2014

John	2014			
Deere	Labour price, € ha^{-1}	rN_sk, € $year^{-1}$	jN_sp, € ha^{-1}	rW_{min}, ha $year^{-1}$
WTS 9660	81.05	7,498.54	33.04	156.19

Table 8. Data table for calculating the turning point of John Deere 9660 WTS 2014

rW_s, ha $year^{-1}$	rN_sk, € $year^{-1}$	rN_sv, € $year^{-1}$	rN_sp, € $year^{-1}$	rVs, € $year^{-1}$
0	7,498.51	0	7,498.51	0
156.16	7,498.51	5,159.52	12,658.03	12,658.03
400	7,498.51	13,216	20,714.51	30,000
800	7,498.51	26,432	33,930.51	60,000
1,200	7,498.51	39,648	47,146.51	90,000
1,600	7,498.51	52,864	60,362.51	120,000
2,000	7,498.51	66,080	73,578.51	150,000
2,400	7,498.51	79,296	86,794.51	180,000
2,800	7,498.51	92,512	100,010.51	210,000
3,200	7,498.51	105,728	113,226.51	240,000

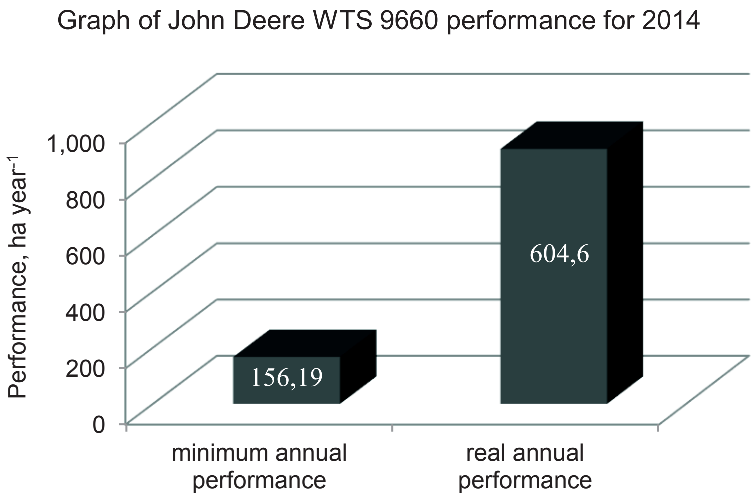

Figure 4. Graph of John Deere WTS 9660 performance for 2014.

John Deere WTS 9660 (2015)

John Deere 9660 WTS (in 2015) had a performance of 905.50 ha year^{-1}, and we calculated the defined turning point (Fig. 5; Table 10) at a value of 166.86 ha year^{-1} (Fig. 6). Thus, in 2015 the grain harvester finished in profits (Table 9).

Table 9. Determination of the minimum annual performance for John Deere 2015

John Deere	2014			
	Labour price, € ha^{-1}	rN_sk, € year^{-1}	jN_sp, € ha^{-1}	rW_{min}, ha year^{-1}
WTS 9660	80.00	7,498.54	35.06	166.86

Table 10. Data table for calculating the turning point of John Deere 9660 WTS in 2015

rW_s, ha year^{-1}	rN_sk, € year^{-1}	rN_sv, € year^{-1}	rN_sp, € year^{-1}	rVs, € year^{-1}
0	7,498.51	0	7,498.51	0
166.86	7,498.51	5,850.11	13,348.62	13,348.62
400	7,498.51	14,024	21,522.51	30,000
800	7,498.51	28,048	35,546.51	60,000
1,200	7,498.51	42,072	49,570.51	90,000
1,600	7,498.51	56,096	63,594.51	120,000
2,000	7,498.51	70,120	77,618.51	150,000
2,400	7,498.51	84,144	91,642.51	180,000
2,800	7,498.51	98,168	105,666,51	210,000
3,200	7,498.51	112,192	119,690.51	240,000

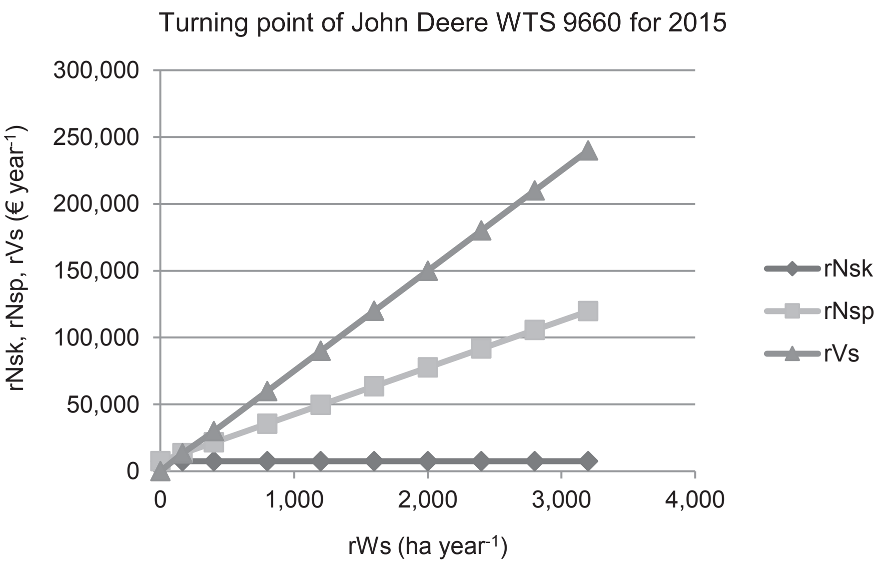

Figure 5. Graph of John Deere WTS 9660 turning point for 2015.

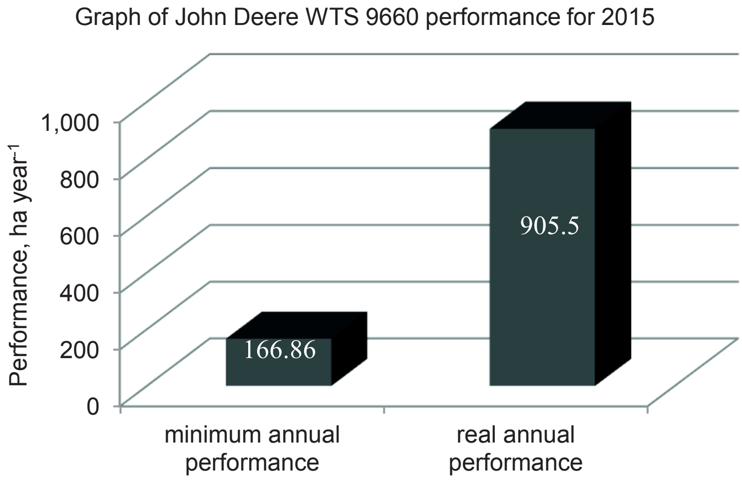

Figure 6. Graph of John Deere WTS 9660 performance for 2015.

After evaluating all the data we came to the conclusion that the organization GoldAgro, Ltd. should increase the performance of individual harvesters. It can be managed by the lowest possible downtime for repairs and maintenance as well as the maximum effort in searching the new customers at the most reasonable means of transport between the different places of operation (Mašek et al. 2015).

CONCLUSIONS

Agriculture in Slovakia has a great potential but organizations that operate in it are just survived from day to day. Without the state subsidies for purchasing agricultural machinery for the renewal of its fleet, it will be very difficult. The competition is intense even within the provision of harvest services. Some organizations offer their work only to cover their costs without any extra profit. The quality of the harvest depends on different types of machines. Nowadays there are various brands of harvesters with different power and size mower clip. GoldAgro, Ltd. organization where we concerned with this issue is the evidence that a high cost of harvesters can bring profit only after quite a few years, if ever. It is important to ensure the efficient use of harvesters and try to raise the actual annual performance. Raising performance should be done by searching of new customers who are interested in harvest services and set price of labour so as to be acceptable to both sides.

The facts that we came to in the research show us that the performance what we achieve depends on technology and service of harvesters. We can see that the older machine that has already been in service for years would lack such performance as a new machine that has advanced technologies built in to achieve the highest possible performance

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about the effect of technological parameters of the surface coating in agricultural and forestry techniques for qualitative parameters, safety and environmental acceptability.

REFERENCES

Beloev, H., Dimitrov, P., Kangalov, P., Stoyanov, K. & Ilieva, D. 2012. Machine operation tests on anti-erosion machine-tractor aggregates for composting and vertical mulching. *Mendeltech international 2012.* International scientific conference, Brno. (in Czech Republic).

Beneš, L., Novák, P., Mašek, J. & Petrášek, S. 2014. John Deere Combine Harvesters Fuel Consumption and Operation Costs. In: 13th International Scientific Conference on Engineering for Rural Development, Jelgava, LATVIA, MAY 20–22, 2015, pp. 13–17.

Bujna, M. & Beloev, C.I. 2015. Tools of risk management in production processes. Ruosse: Angel Kanchev University of Rousse, 105 pp. (in Bulgaria).

Bulgakov, V., Melnik, V., Mohammed, A., Korenko, M. & Kollárová, K. 2016. Methodology of processing the results of field experiment monitoring of the technological procedure of sowing. In *Research in agricultural engineering* **62**, pp. 30–36.

Craessaerts, G., De Baerdemaeker, J. & Saeys, W. 2010. Fault diagnostic systems for agricultural machinery. *Biosystems Engineering* **106**(1), 26–36.

de Toro, A., Gunnarsson, C., Lundin, G. & Jonsson, N. 2012. Cereal harvesting – strategies and costs under variable weather conditions. *Biosystems Engineering* **111**(4), 429–439.

Findura, P., Turan, J., Jobbágy, J., Angelovič, M. & Ponjican, O. 2013. Evaluation of work quality of the green peas harvester Ploeger EPD 490. In *Research in agricultural engineering* **59**, pp.56–60.

Hanna, H.M. & Jarboe, D.H. 2011. Effects of full, abbreviated, and no clean-outs on commingled grain during combine harvest. *Applied Engineering in Agriculture* **27**(5), 687–695.

Korenko, M., Frančák, J., Tkáč, Z., Kročko, V., Kaplík, P. & Daňo, P. 2012. Evaluation of operational reliability of grain harvester. In *Zbirnik naukovych prac Vinničkogo nacionaľnogo agrarnogo universitetu.* Kijev: Ministerstvo agrarnoj politiki Ukraini, pp. 24–32. (in Ukraine).

Korenko, M., Bujna, M., Földešiová, D., Dostál, P. & Kyselica, P. 2015. Risk analysis at work in manufacturing organization. In *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* **63**, pp. 1493–1497.

Korenko, M., Frančák, J., Kročko, V., Földešiová, D., Dragula, P. & Bulgakov, V. 2012. Analysis methods for measuring system by repeatability and reproducibility. In Konstruovannja, vyrobnictvo ta ekspluatacija silskogospodarskich mašin. pp. 65–70 (in Ukraine).

Lee, D.H., Kim, Y.J., Choi, C.H., Chung, S.O., Nam, Y.S. & So, J.H. 2016. Evaluation of operator visibility in three different cabins type Far-East combine harvesters. *International Journal of Agricultural and Biological Engineering* **9**(4), 33–44.

Mašek, J., Novák, P. & Pavlíček, T. 2015. Evaluation of Combine Harvester Fuel Consumption and Operation Costs. In: *14th International Scientific Conference: Engineering For Rural Development.* Jelgava, LATVIA, MAY 20–22, 2015, pp. 78–83.

Nozdrovický, L., Macák, M., & Šima, T. 2013. Current trends in the development of agricultural machinery and their impact on the knowledge and skills of the human factor. In: *5th International Conference on Trends in Agricultural Engineering.* Czech University of Life Sciences Prague, Dept Systems Eng, Kamycka 129, Prague 6 165 21, Czech Republic, Prague, Czech Republic, Sep 03–06, 2013, pp. 467–474.

Prístavka, M. & Bujna, M. 2013. Use of Satatical Methods in Quality Control. In: *Acta technologica agriculturae*. SUA in Nitra, Nitra pp. 33 –36. (in Slovak Republic).

Prístavka, M. & Bujna, M. 2014. Monitoring the Capability of Production Equipment in Organization. In: *Acta technologica agriculturae.* SUA in Nitra, Nitra pp. 39–43. (in Slovak Republic).

Prístavka, M., Bujna, M. & Korenko, M. 2013. Reliability Monitoring of Grain Harvester in Operating Conditions. *Journal of Central European Agriculture* **14**, 1436–1443.

Singh, M., Verma, A. & Sharma, A. 2012. Precision in Grain Yield Monitoring Technologies: A Review. *AMA-Agricultural Mechanization in Asia Africa and Latin America* **43**(4), 50–59.

Vladut, V., Moise, V., St Biris, S. & Paraschiv, G. 2012. Determining the cost matrix of straw cereals combine harvesters, according to equipment quality nad engine power. In: *40th International Symposium on Agricultural Engineering.* Opatija, CROATIA, FEB 21–24, 2012, pp. 333–343.

Žitňák, M., Kollárová, K., Macák, M., Prístavková, M. & Bošanský, M. 2015. Assessment of risks in the field of safety, quality and environment in post-harvest line. In *Research in agricultural engineering* **61**, pp. 26–36.

Žitňák, M., Macák, M. & Korenko, M. 2014. Assessment of risks in implementing automated satellite navigation systems. In *Research in agricultural engineering* **60**, pp. 16–24.