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Coefficients of repair and maintenance costs for axial and transverse combine harvesters in Argentina

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Abstract

Maintenance and repair cost (M&RC) coefficients were estimated for grain harvesters in Argentina. Two representative machines were selected, the Deutz-Fahr Optima 550 and CASE Axial Flow 2188, both equipped with wheat and maize platforms. Estimated coefficients were 6.685 and 7.143 [10^{-5} h^{-1}] respectively for the Deutz and CASE combines using wheat platforms; and 7.082 and 8.294 [10^{-5} h^{-1}] using maize platforms. The confidence intervals for these values were estimated through regression analysis and Monte Carlo simulation. Finally, in an evaluation of several harvesters (including grain, sugar cane and cotton harvesters), M&RC coefficients were observed to show a mean decreasing tendency of around –1.5% per year.

Key words: farm machinery, farm management, costs.

Resumen

El coeficiente de gastos de conservación y reparación de cosechadoras de grano de cilindro transversal y axial en Argentina

En el presente trabajo se calcularon los coeficientes de gastos de conservación y reparación de dos cosechadoras de grano, Deutz-Fahr Optima 550 de cilindro transversal y CASE Axial Flow 2188 de cilindro axial, ambas con plataformas trigo/soja y maíz. Los valores obtenidos fueron, para la primera y segunda cosechadora, respectivamente, de 6,685 y 7,143 [10^{-5} h^{-1}] con plataforma para trigo; y de 7,082 y 8,294 [10^{-5} h^{-1}] con plataforma para maíz. Se calcularon, además, funciones de gastos acumulados a lo largo de la vida útil de las máquinas, las que permitieron obtener estimadores de las varianzas de los gastos y calcular intervalos de confianza para los coeficientes de gastos de conservación y reparación mediante la técnica de simulación Monte Carlo. Finalmente se analizó la posible existencia de una tendencia general de largo plazo en los coeficientes de cosechadoras de distinto tipo, que resultó estadísticamente significativa y del orden del –1,5% anual.

Palabras clave: maquinaria agrícola, administración rural, costos.

Introduction

The maintenance and repair cost coefficient (M&RCC) has been defined as the quotient between the mean hourly cost of maintenance and repair of a machine and its purchase value (Frank, 1977). It is therefore expressed in [h^{-1}]. The M&RCC of a machine includes the costs of lubricants and replacing worn parts, but does not account for parts replaced because of accidental breakage. Also included in the M&RCC are the general labour costs generated by maintenance procedures along with costs related to specialised man power needed to replace worn parts. The M&RCC of agricultural machinery is widely used in cost evaluations such as calculating gross farming costs.

The M&RCCs of transverse cylinder grain harvesters used in Argentina were calculated on two occasions: in 1962, at a technical meeting of the Seminary of Costs of Agricultural Machinery[1], and in 1978 by Pizarro and Cacciamani, technicians of the Agricultural Economics Section of the *Estación Experimental Regional Agropecuaria Pergamino* (Pergamino Farming Regional Experimental Station) of the *Instituto Nacional de Tecnología Agropecuaria (INTA)* (National Institute of Farming Technology). Both these evaluations were based on personal and professional criteria related to the three

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[1] This unpublished estimate was proposed by the Seminary's participants (R. Frank, University of Buenos Aires, 2002, personal communication).

Table 1. Components of the maintenance and repair coefficient in estimates made in 1962 and 1978

Component	1962 estimate [10^{-5} h^{-1}]	1978 estimate [10^{-5} h^{-1}]
Oil lubrication		0.628
Sump oil	0.752	—
Transmission oil	0.156	—
Grease lubrication	0.137	1.472
Misc. repairs	10.000	—
Spare parts	—	6.878
Labour	—	1.842
Total	11.044	10.819

main points: mean hourly oil lubrication costs, mean hourly grease lubrication costs and mean hourly miscellaneous repair costs. Table 1 shows the costs of these components calculated on these two occasions. The evaluation performed in 1962 refers to a generic machine with a 4.8 m (16 foot) wheat platform, assigned a useful life of 5000 hours. The estimates made in 1978 were based on the costs of a generic harvester used in the Pergamino region (Buenos Aires province) with no specification made of the make or model, nor the working width; its useful life being estimated at 10 years. Neither estimate discriminated between costs generated by the harvester and the platform. Despite both being very general estimates, the M&RCCs were within some 11 [10^{-5} h^{-1}] of each other.

The North American literature quotes the following M&RCCs for transverse cylinder harvesters: 16.488 [10^{-5} h^{-1}] without lubricants[2] [Bowers (1970), pages 12-14 of the appendix; Bowers (1975) page 91] for machines of 2000 h of useful life; 27 [10^{-5} h^{-1}] [Hunt (1977), page 69 and (1995), page 74, according to a table attributed to Kepner] for an estimated useful life of 2000 h; 18.58 [10^{-5} h^{-1}] [Hunt (1977), page 71, calculated by regression for a maximum useful life of approximately 3000 h]; 13.371 [10^{-5} h^{-1}] [Hassan and Larson (1978), from an evaluation conducted in the state of Arizona], 11.298 [10^{-5} h^{-1}] [Hassan and Larson (1978), expected value according to the regression in the expression used by the American Society of Agricultural Engineers, ASAE]; and 25 [10^{-5} h^{-1}] [Kepner *et al*. (1980), page 34] for harvesters of a useful life estimated at 2000 h.

In the last few years, grain harvesters have increased in their work capacity and new machines with axial threshing systems have emerged. The aim of the present study was: a) to review M&RCCs calculated for transverse cylinder machines and to provide a first M&RCC estimate for an axial cylinder machine in Argentina; b) to establish confidence intervals for these estimates; and c) to determine whether grain, sugar cane and cotton harvesters show any long-term tendency, following the line of work initiated in a previous study by the present author (Frank, 2002).

Material and methods

Two representative harvesters were selected: the Deutz-Fahr Optima 550 which has a transverse cylinder and a 6.9 m (23 foot) platform for wheat/soy or a maize Mainero 2000 platform for 10 furrows at 70 cm, and the CASE Axial Flow 2188 with a wheat/soy 9 m (30 foot) platform or CASE 1083 maize platform[3] for 8 furrows at 70 cm. Based on operation and maintenance manuals and conversations with the technical service heads of both suppliers (AGCO and CASE-New Holland, respectively), repair and maintenance costs were estimated and are provided in annexes to this paper. Prices and salaries were derived from: a) spare part and lubricant prices quoted or recommended by the manufacturer (as effective in July 2001, not including value added tax, VAT); b) new purchase prices for each harvester and their corresponding platforms (harvesting cutterheads) in the same marketing conditions; c) a mean hourly machine operator salary equivalent to the gross salary (i.e., the basic wage plus extras, and company contributions) of the category «tractor operator» stipulated by the *Comisión Nacional de Trabajo Agrario* (National Agricultural Work Commision) and resolutions of the *Administración Federal de Ingresos Públicos, AFIP* (Federal Administration of Public Income); d) a modal value was assigned to the workshop-hour (excluding VAT) according to conversations with dealer repair services of the suppliers AGCO and CASE-New Holland. The mean «basic» salary of the «tractor operator» category (including no extras or social security contributions) varied according to the province, thus the simple mean for the

[2] According to the author's data, a value of 2.160 needs to be added to the M&RCC for maize and sorghum harvesters and one of 1.350 for fine grain harvesters. For this calculation, a cost in lubricants corresponding to 15% of the fuel costs was considered. With lubricants, M&RCCs are 17.838 for fine grain machines and 18.648 for maize and sorghum harvesters.

[3] We considered the most commonly used harvester/platform combinations as defined by each manufacturer.

Table 2. Mean tractor operator salary for the provinces of Buenos Aires, Córdoba, Entre Ríos and Santa Fe

Component	Buenos Aires	Córdoba	Entre Ríos	Santa Fe
Basic tractor operator salary [$/month]	317.51	300.60	300.60	300.60
Extras (extra pays, holiday pay and pay rises) [%]	14.41	14.41	14.41	14.41
Tax and other employer contributions [%]*	23.00	23.00	23.00	23.00
Social security [%]	18.50	18.50	18.50	18.50
Total salary [$/month] (22 workdays/month)	495.05	468.68	468.68	468.68

* Decree 814/01 of the *Poder Ejecutivo Nacional* established a 21% employer contribution for production companies effective from July 1, 2001.

provinces Buenos Aires, Córdoba, Entre Ríos and Santa Fe was used. Table 2 details the components of the tractor operator salary for these provinces.

The exchange rate applicable at the time of study (July 2001) was 1US$=1$, according to the Conversion Law (No. 23.928/91) approved in April 1991 and rescinded in January 2002.

Results

Table 3 provides details of the maintenance and repair costs of the harvesters Deutz-Fahr Optima and CASE Axial Flow 2188 according to Central Product Classification (CPC version 1.0 from United Nations) for 1998, and the purchase value of each machine. The ori-

Table 3. Details of the maintenance and repair costs of teh Deutz-Fahr Optima and Case Axial Flow 2188 grain harvesters

CPC	Description	Deutz-Fahr		CASE	
		[$ h^{-1}]	[%]	[$ h^{-1}]	[%]
31210	Sawn wood (edges and blocks)	—	—	0.0120	0.09
33310	Gasoline (common, super, and laboratory grade)	—	—	0.0046	0.03
33380	Motor, transmission and hydraulic oil	0.7419	7.44	0.7971	5.87
33380	Grease-various types	0.8268	8.29	0.1547	1.14
33380	Break fluid and additives	0.0004	0.00	0.3341	2.46
34210	Refrigerant gas for A/C	0.0102	0.10	0.0375	0.28
36113	Other new rubber tyres	0.6224	6.24	1.1953	8.81
36240	Vulcanised rubber belts or bands	1.7747	17.80	0.9170	6.76
36310	Plastic bars	0.0005	0.00	—	—
36330	Ratchets or membranes (plastic)	0.0025	0.02	—	—
42991	Chains and their iron or steel components	0.1800	1.81	—	—
43151	Parts and pieces of piston engines (injectors, valves, rings, pistons etc.)	0.0358	0.36	0.6015	4.43
43310	Ball or roller bearings	0.2992	3.00	1.4653	10.80
43320	Transmission shaft; gear boxes and reducers; clutches and shaft couplers	0.1234	1.24	—	—
43915	Oil filters	0.1333	1.34	0.5739	4.23
43915	Fuel filters	0.0271	0.27	0.1727	1.27
43915	Air filters	0.0511	0.51	0.2697	1.99
44130	Harvesters: conveyors	2.0341	20.40	3.8663	28.49
44130	Harvesters: cutter-blades and platform	0.4293	4.31	1.4477	10.67
46420	Electric battery	0.1405	1.41	0.1493	1.10
46910	Lamps, bulbs, thermal emitters and devices not listed above	0.0068	0.07	0.1034	0.76
87159	Machinery and equipment maintenance and repair services not listed above	0.8966	8.99	0.8090	5.96
no number	Machine operator labour costs	1.6341	16.39	0.6616	4.87
	Total [$ h^{-1}]	9.9706	100.0	13.5726	100.0
	Purchase value [$]	149.157		190.000	

ginal estimates are detailed in the annexes. Given that both machines are sold with a wheat/soy platform, this combination was used as reference. Estimates for the maize platform are separately listed in the annexes.

The quotient between the mean hourly maintenance and repair cost and the purchase value of each machine gives an M&RCC for the Deutz-Fahr of 6.685 [10^{-5} h^{-1}] and a coefficient of 7.143 for the CASE [10^{-5} h^{-1}], including costs for the wheat platform in both cases.

As already mentioned, this analysis attempts to extend the findings of a previous report on sugar cane and cotton harvesters. In an effort to make both reports comparable, the M&RCC was calculated for machines of different age. This was done by adding mean hourly repair or replacement costs of parts of similar replacement age and dividing this sum by the purchase price of the machine. Table 4 shows data for selected ages.

Next, regression functions for marginal costs were fitted as a function of machine age according to the following procedure:

a) Cumulative cost series were established according to the age of each machine. The corresponding incremental quotients $\Delta y/\Delta x$ were calculated, where «x» is the mean age in hours and «y» the total cumulative cost of all the repairs. Different functions were fitted to explain $\Delta y/\Delta x = f(x)$. The potential function was found to best fit the data series. Goodness of fit was measured using the adjusted determination coefficient R^2. In this first stage, regression coefficients were determined using the ordinary least squares (OLS) estimator $ß_{OLS}=[X^TX]^{-1}X^TY$, where $ß_{OLS}$ is the regression coefficient matrix and X and Y are the corresponding transformations of x and $\Delta y/\Delta x$ used to linearise the different functional forms.

b) Once the potential function had been selected, the coefficients were recalculated using the generalised least squares (GLS) estimator $ß_{GLS} = (X^T\Omega^{-1}X)^{-1}X^T\Omega^{-1}Y$, where X and Y are the matrices mentioned above and Ω is a diagonal matrix made up of the squared errors $U^*_i{}^2$ of the OLS model, to correct the bias due to heteroscedasticity in estimating the standard deviation of the regression coefficients. Pindyck and Rubinfeld (1981) and Judge *et al.* (1985), theoretically reviewed the estimator $ß_{GLS}$, whose use for calculating maintenance and repair costs was subsequently validated by Frank (2002). The variance-covariance matrix of the coefficients of regression $ß_{GLS}$ is $\Sigma^2(ß_{GLS}) = (X^T\Omega^{-1}X)^{-1}$. Table 5 shows the results obtained.

The functions calculated correspond to the expression $Y_i = X_iß+U_i$. If we denote the potential function exponent $ß_1^* = \lambda_1$ and the ordinate at the origin $ß_0^* = \ln(\lambda_0)$, and $X_i=\ln(x_i)$ and $Y_i = \ln(\Delta y_i/\Delta x_i)$, the differential equation can be resolved as:

$$\frac{dy}{dx} = \lambda_0 x^{\lambda_1} \Rightarrow \int dy = \lambda_0 \int x^{\lambda_1} dx + C =$$

$$= \frac{\lambda_0}{\lambda_1 + 1} x^{\lambda_1 + 1} + C \quad \text{for } (\lambda_1 \neq -1)$$

Table 4. Partial coefficients of maintenance and repair for Deutz-Fahr and CASE Axial Flow 2188 harvesters according to the platform and age of the machine

Age [h]	M&RCC [10^{-5} h^{-1}]			
	Deutz-Fahr		CASE Axial Flow 2188	
	Wheat/soy 6.9 m platform	Maize plt. 10 furrows at 70 cm	Wheat/soy 9 m	Maize plt. 8 furrows at 70 cm
1 000	4.759	4.452	1.654	3.018
2 000	5.700	6.205	4.573	5.891
3 000	5.799	6.369	6.092	7.425
4 000	6.377	6.777	6.318	7.654
5 000	6.533	6.937	6.358	7.694
5 500			6.550	
6 000	6.558	6.963		
7 000			6.810	7.957
7 500	6.567	6.967	6.810	7.957
9 000	6.629	7.031	6.812	7.959
10 000			7.143	8.294
12 000	6.656	7.058		
15 000	6.685	7.082		

Table 5. Coefficients of regression of the model $\ln [\Delta y/\Delta x] = ß_1 \ln[x] + ß_0$ of marginal costs according to machine age

Platform	Regression estimator	Deutz-Fahr harvester		CASE harvester	
		$ß_1$	$ß_0$	$ß_1$	$ß_0$
Wheat/soy	$ß^{*T}$	0.1185	1.2636	0.5564	–2.2196
	$\Sigma(ß)_{ii}^{*T}$	0.0249	0.2170	0.0081	0.0631
	t statistic*	4.7511	5.8229	69.068	–35.157
Maize	$ß^{*T}$	0.1126	1.3495	0.3509	–0.2578
	$\Sigma(ß)_{ii}^{*T}$	0.0396	0.3438	0.0643	0.5589
	t statistic*	2.8423	3.9250	5.4534	–0.4613

* Indicates an estimator of the true value.

where C is a constant equal to zero, since the cost of maintaining a new machine is null.

c) Based on the deviations of the regression coefficients and the regression error for an age x_i at the end of the machine's useful life[4], it was considered that $\sigma^2(Y_i) = X_i^2\,\sigma^2(ß_1) + \sigma^2(ß_0) + 2\,X_i\,\sigma(ß_1;ß_0) + \sigma^2(U_i)$. This expression allows us to calculate the variance of Y_i to simulate possible M&RCC values using the following equation obtained by resolving the differential equation:

$$M\&RCC = \frac{e^{Y_i + Z_2\sigma(Y_i)}}{1 + (ß_1 + z_1\sigma_{ß1})}\,\frac{1}{V_N}$$

where z is a normally distributed random variable and V_N is the cost of the new machine. Generating random z values gives a distribution of results that serves to establish a confidence interval for the M&RCC. In our case, we chose to perform 1000 repetitions of z, from which we obtained the confidence intervals for $P\{A<M\&RCC< B\}=0.9$ presented in Table 6.

The confidence interval was established from the empirical cumulative probability function derived from simulation. The functional form of the model used in the simulation suggests that the M&RCCs do not show a normal distribution. This presumption can be observed in Figures 1A and 1B, which provide empirical probability distributions of the M&RCCs of both harvesters for wheat/soy and maize platforms. It may be observed that the distribution of the M&RCC is right-asymmetric (positive asymmetry).

Table 6. Confidence intervals for $P\{A < M\&RCC < 8\} = 0.9$

Harvester	Platform	A	B
Deutz-Fahr	Wheat/soy	5.689	7.319
	Maize	5.971	7.921
CASE	Wheat/soy	3.766	10.239
	Maize	5.218	11.383

In the last stage of the study, we determined whether the M&RCCs of different harvesters showed any long-term trends. To this end, we constructed a X matrix including 26×5 independent variables and a Y matrix containing M&RCCs expressed as units of $10^{-5}h^{-1}$. The independent variables were 4 binary variables (3 indicative of the type of harvester and a fourth variable indicating the country where the coefficient was calculated) and a discrete variable referring to the year in which the M&RCC was calculated, counted from the year 1960 which was taken as zero. Both matrices are provided in Table 7. The criteria used to assign a year to each M&RCC was that of the oldest bibliographic reference for each case. In addition, if there were appreciable differences in the useful life assigned by North American and Argentinian authors to the different harvesters, costs at 3,000 h were taken as the cost coefficient in an effort to use comparable figures, provided local references contained this information.

Assuming a heteroscedastic structure of the residuals[5], regression coefficients and their corresponding t statistics* are presented in Table 8.

It may be observed that all the coefficients were significant at a rejection level H_0) $ß_i=0$ of 5%. These findings indicate that the M&RCCs calculated for Argenti-

[4] In an effort to standardise results we selected an age of 12,000 h for both harvesters to establish the confidence intervals for their M&RCCs.

[5] As all measures came from different experimental conditions, a pure heteroscedastic error structure was assumed, and the Durbin-Watson test on residuals was performed. The Durbin-Watson test yielded no conclusive evidence of autocorrelation among residuals ($d^*=1.69$; $d_L=0.979$ and $d_S=1.873$).

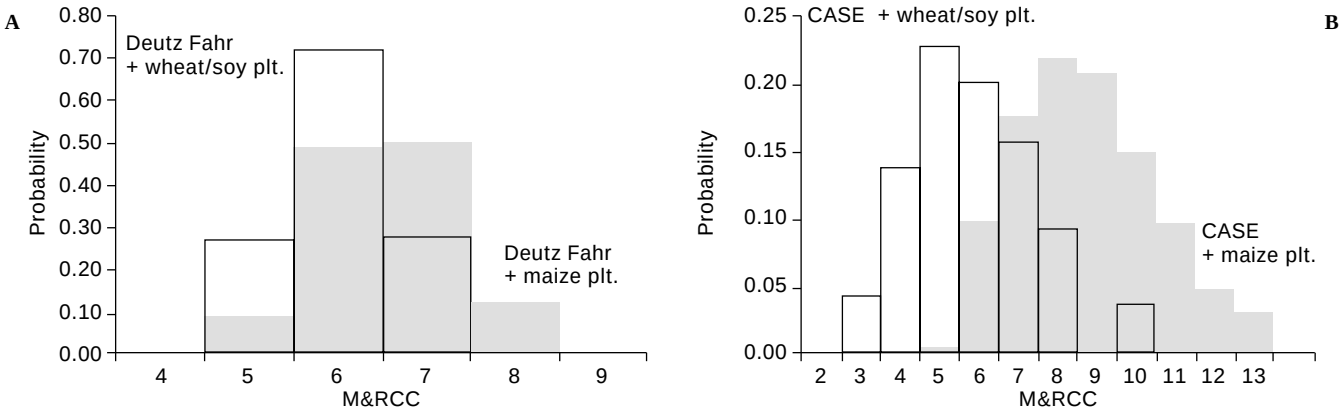

Figure 1. Graph of the empirical probability distribution of M&RCCs for: A) The Deutz-Fahr Optima 550 harvester with a wheat/soy platform (outlines) or maize platform (shaded grey). B) The CASE Axial Flow 2188 harvester with a wheat/soy platform (outlines) or maize platform (shaded grey).

na are lower than those reported by North American authors. Moreover, a generally decreasing tendency in the M&RCC was observed for the grain, sugar cane and cotton harvesters. The effective yearly reduction rate for each type of harvester in Argentina can be determined from the M&RCC estimated for the years 0 and 41 using the expression $\{[E(M\&RCC_{41})/E(M\&RCC_0)]^{1/41}-1\}\times 100$. This procedure gives the rates: –2.237%, –1.081%, and

Table 7. Y matrix comprised of M&RCCs and X matrix comprised of independent variables

Y matrix	X matrix				
	Years since 1960	Argentina	Sugar cane harvester	Cotton harvester	Grain harvester
8.230	21	1	1	0	0
12.21	16	1	1	0	0
14.37	16	1	1	0	0
30.00	25	1	0	1	0
29.98	10	0	0	1	0
30.00	20	0	1	0	0
35.00	20	0	0	1	0
26.00	17	0	0	1	0
26.70	35	0	0	1	0
12.59	29	0	1	0	0
10.73	29	0	0	1	0
8.425	41	1	1	0	0
8.879	41	1	0	1	0
11.04	2	1	0	0	1
10.82	18	1	0	0	1
17.84	10	0	0	0	1
18.65	10	0	0	0	1
27.00	17	0	0	0	1
18.58	17	0	0	0	1
13.371	18	0	0	0	1
11.298	18	0	0	0	1
25.00	20	0	0	0	1
5.799	41	1	0	0	1
6.369	41	1	0	0	1
6.092	41	1	0	0	1
7.425	41	1	0	0	1

Table 8. M&RCC regression coefficients according to the year, place and type of harvester

Variable	$ß_{GLS}$* matrix	$\Sigma(ß)_{ii}$* matrix	t statistic*
Years since 1960	–0.213	0.014	–15.55
Argentina	–7.527	0.254	–29.6
Sugar cane harvester	24.86	0.505	49.2
Cotton harvester	32.06	0.355	90.3
Grain harvester	22.19	0.261	85.2

–1.727 for grain, sugar cane and cotton harvesters, respectively. The mean yearly effective rate for all the harvesters is given by expected M&RCCs for the years 0 and 41 assigning binary variables the value of 0.33. The effective yearly rate calculated in this manner was –1.536%.

Discussion

On simple inspection of the results, it would appear that the coefficients of maintenance and repair for the current transverse cylinder machines are lower than those generally reported for Argentina, given that the latter fall outside the confidence limits estimated by the simulation process. Further, all the values cited in North American references also escape our confidence interval.

The CASE axial harvester showed a higher M&RCC than the traditional Deutz-Fahr harvester. The transverse cylinder harvester was related to higher costs in lubricants and belts, while the axial harvester clearly generates more costs in replacing bearings. Machine operator costs were higher for the traditional harvester, being associated with more lubrication tasks. This does not necessarily indicate the greater technical complexity of one system or another, but may rather be attributed to differences in the particular designs used by each manufacturer. In other words, focusing on one particular type of machine can lead to biased results. The results presented here should therefore be backed up by more extensive studies involving larger sample sizes.

The fall in the M&RCC over time need not necessarily be explained by an increased durability of the different spare parts or by a long-term tendency of the price of spare parts to drop relative to the price of the new machine. It could be that the fall is related to the behaviour of some other factor (e.g., the working width) that varies over time. Unfortunately, the scarce reference made to the technical characteristics of these machines in the past precludes drawing any further conclusions regarding this point.

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References

BOWERS W., 1970. Modern concepts of farm machinery management. Appendix table of contents. Stipes Publishing Company, Champaign, Illinois, USA. 60 pp.

BOWERS W., 1975. Fundamentals of machine operation. Machinery management. John Deere Educational Media. John Deere Service Publications, Dept. F. Deere & Company, Moline, Illinois, USA. 182 pp.

FRANK R., 1977. Costos y administración de la maquinaria agrícola. Ed Hemisferio Sur. Buenos Aires, Argentina. 385 pp.

FRANK L., 2002. Revisión del coeficiente de gastos de conservación y reparación de cosechadoras de algodón y caña de azúcar en Argentina. Revista de Agricultura 77(3), 329-346.

HASSAN G., LARSON D., 1978. Combine capacity and costs. T ASAE 21(6), 1068-1070.

HUNT D., 1977. Farm power and machinery management. Laboratory manual and workbook. 7th ed. Iowa State Univ. Press. Ames, Iowa, USA. 365 pp.

HUNT D., 1995. Farm power and machinery management. 9th ed. Iowa State Univ. Press. Ames, Iowa, USA. 363 pp.

JUDGE G., GRIFFITHS W., CARTER HILL R. LUTKEPOHL H., CHAO-LEE T., 1985. The theory and practice of econometrics. 2nd ed. Wiley Series in Probability and Mathematical Statistics. John Wiley & Sons, USA. 1019 pp.

KEPNER R., BAINER R., BARGER E., 1980. Principles of farm machinery. 3rd ed. The Avi Publishing company Inc. Westport, Connecticut, USA. 527 pp.

PINDYCK R., RUBINFELD D., 1981. Econometric models and economic forecast. 2nd ed. Mc Graw-Hill, New York, USA. 630 pp.

PIZARRO J., CACCIAMANI M., 1978. Costo estimativo de la cosecha de trigo. Sección de Economía Agrícola de la Estación Experimental Regional Agropecuaria Pergamino INTA, Argentina. Costos No. 29, pp. 1-8.

Annex 1. Deutz-Fahr Optima 550 harvester

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
1. Deutz BF6L 913C engine (220 HP)									
Change engine oil: oil API CF-CF4 (ACEA D4-D5) (1)	15 000	38	3	0.20	2.70			106.53	0.0071
Change engine oil: oil (2)	15 000	38	3	0.20	2.70			106.53	0.0071
Change engine oil: oil (3)	300	38	3	0.20	2.70			106.53	0.3551
Change oil filter (1)	15 000	1	12	0.20	2.70			12.60	0.0008
Change oil filter (2)	15 000	1	12	0.20	2.70			12.60	0.0008
Change oil filter (3)	300	1	12	0.20	2.70			12.60	0.0420
Check oil level (1)	15 000			0.10	2.70			0.27	0.0000
Check oil level (2)	15 000			0.10	2.70			0.27	0.0000
Check oil level (3)	10			0.10	2.70			0.27	0.0270
Check valve gap with engine cold (1) and (2)	7 500					0.30	12.00	3.60	0.0005
Check valvle gap with engine cold (3)	600					0.30	12.00	3.60	0.0060
Check condition and tension of belts	10			0.05	2.70			0.14	0.0135
Replace alternator belt	12 000	1	155	1.00	2.70			157.69	0.0131
Replace turbo-fan belts	12 000	2	155	1.50	2.70			314.04	0.0262
Drain water from trap and primary fuel filter (1) and (2)	15 000			0.05	2.70			0.14	0.0000
Drain water from trap and primary fuel filter (3)	10			0.05	2.70			0.14	0.0135
Clean water trap sieve (1) and (2)	15 000			0.15	2.70			0.41	0.0000
Clean water trap sieve (3)	300			0.15	2.70			0.41	0.0014
Change primary fuel filter element (1) and (2)	15 000	1	6	0.10	2.70			5.90	0.0004
Change primary fuel filter element (3)	300	1	6	0.10	2.70			5.90	0.0197
Change secondary fuel filter element (1) and (2)	15 000	1	5	0.10	2.70			4.84	0.0003
Change secondary fuel filter element (3)	600	1	5	0.10	2.70			4.84	0.0081
Clean air filter	240			0.30	2.70			0.81	0.0034
Change air filter element	1 200	1	42	0.20	2.70			42.3	0.0353
Change air filter safety element	1 200	1	20	0.20	2.70			20.0	0.0167
Check/clean cooling vanes	300			1.00	2.70			2.70	0.0090
Regulate oil dispensers of rocker arms *(not applicable to new harvesters)*	7 500					0.25	12.00	3.00	0.0004
Check manifold attachment (1) and (2)	7 500			0.05	2.70			0.14	0.0000
Check manifold attachment (3)	600			0.05	2.70			0.14	0.0002
Check injection pump (1)	15 000					1.00	12.00	12.00	0.0008
Check injection pump (3)	3 000					1.00	12.00	12.00	0.0040
Check injectors (1)	15 000					1.00	12.00	12.00	0.0008
Check injectors (3)	1 200					1.00	12.00	12.00	0.0100
Replace injectors *(primed and calibrated)*	6 000	6	36			0.67	12.00	223	0.0372
Check turbofeeder and conduits are fast (1)	15 000			0.08	2.70			0.22	0.0000
Check turbofeeder and conduits are fast (3)	600			0.08	2.70			0.22	0.0004
Check radial and axial play of the turbofeeder (1)	15 000					0.25	12.00	3.00	0.0002
Check radial and axial play of the turbofeeder (3)	3 000					0.25	12.00	3.00	0.0010
Empty diesel tank	750			0.17	2.70			0.45	0.0006
Check warning systems (1)	15 000					2.00	12.00	24.00	0.0016
Check warning systems (3)	750					2.00	12.00	24.00	0.0320
Engine rectification	9 000					70.00	12.00	840.00	0.0933
2. Transmission									
Check oil level of gear box, final gear reducers and differential (2)	15 000			0.10	2.70			0.27	0.0000
Check oil level of gear box, final gear reducers and differential (3)	300			0.10	2.70			0.27	0.0009
Change oil (first change at 300 h): oil API GL5 (MIL-L-2105 C), viscosity SAE 80W/90	15 000	16	3	0.30	2.70			53.73	0.0036

Annex 1 (cont.)

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
Change oil (max. once a year)	600	16	3	0.30	2.70			53.73	0.0895
Change transmission oil filter (first change at 600 h)	600	1	16	0.20	2.70			16.63	0.0277
Change hydrostatic transmission oil filter	900	1	16	0.20	2.70			16.63	0.0185
Change hydrostatic transmission oil	2 000	38	3	0.30	2.70			126.49	0.0632
Clean radiator of hydrostatic transmission oil	10			0.25	2.70			0.68	0.0675
Check gear change mechansism and adjust if necessary (2)	15 000			0.50	2.70			1.35	0.0001
Check gear change mechansism and adjust if necessary (3)	600			0.50	2.70			1.35	0.0023
Check clutch oil level	300			0.08	2.70			0.22	0.0007
Replace engine-speed controller belt	2 000	1	155	1.00	2.70			157.69	0.0788
Replace speed controller-clutch belt	2 000	1	155	1.00	2.70			157.69	0.0788
Replace ball bearings of the differential *(includes changing of ball bearings and roller)*	5 000					15.00	12.00	180.00	0.0360
Ball bearings	5 000	4	66					264.52	0.0529
Roller	5 000	1	58					57.73	0.0115
Replace differential ratchets *(labour costs along with ball bearings change)*	5 000	2	6					12.37	0.0025
Repair clutch and axle *(includes roller and axle change)*	5 000					4.00	12.00	48.00	0.0096
Rollers	5 000	2	83					165.85	0.0332
Axle	5 000	1	278					277.58	0.0555
3. Switches, levers etc.									
Check accelerator regime controller of the threshing cylinder (1) and (2) *(takes 2 people 5 min)*	7 500					0.16	12.00	1.92	0.0003
Check accelerator regime controller of the threshing cylinder (3)	300					0.16	12.00	1.92	0.0064
Check forward speed controller (1) and (2)	7 500					0.16	12.00	1.92	0.0003
Check forward speed controller (3)	600					0.16	12.00	1.92	0.0032
Check conditions and tension of chains and belts	10			0.08	2.70			0.22	0.0216
4. Hydraulic system									
Check all hydraulic functions	10			0.20	2.70			0.54	0.0540
Check oil level	10			0.10	2.70			0.27	0.0270
Change hydraulic system oil (2)	15 000	25	3	0.17	2.70			67.97	0.0045
Change hydraulic system oil (3)	900	25	3	0.17	2.70			67.97	0.0755
Change filter element (2)	15 000	1	16	0.08	2.70			16.30	0.0011
Change filter element (3)	900	1	16	0.08	2.70			16.30	0.0181
Clean tank breather (2)	15 000			0.17	2.70			0.45	0.0000
Clean tank breather (3)	600			0.17	2.70			0.45	0.0007
Regulate ascent and descent speed of the cutting head	10			0.08	2.70			0.22	0.0216
Check hydrostatic steering (1)	15 000					0.17	12.00	1.99	0.0001
Check hydrostatic steering (2)	7 500					0.17	12.00	1.99	0.0003
Check hydrostatic steering (3)	600					0.17	12.00	1.99	0.0033
Check and clean oil cooler	10			0.20	2.70			0.54	0.0540
Check pressurised oil hose joints (2) *(along with general test)*	15 000							0.00	0.0000
Check pressurised oil hose joints (3) *(along with general hydraulic function test)*	600							0.00	0.0000
5. Cutting head and transporter duct									
Check oil level of the mill activator hydraulic system	10			0.03	2.70			0.09	0.0089

Annex 1 (cont.)

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
Check the cutting head compensator (1) *(includes checking beam, mill, conveyor, blade, chains and belts)*	15 000					4.50	12.00	54.00	0.0036
Check cutting head compensator (2)	7 500					4.50	12.00	54.00	0.0072
Check cutting head compensator (3)	600					4.50	12.00	54.00	0.0900
Check cutter-blade condition and functioning	10			0.08	2.70			0.22	0.0216
Replace blade (for soy and furrow crops)	600	1	184		2.70			184.00	0.3067
Replace blade (for wheat and fine grains)	1 500	1	184		2.70			184.00	0.1227
Check blade activator oil level	10			0.03	2.70			0.09	0.0089
Change blade reducer activator oil	200	1.25	3	0.17	2.70			4.58	0.0229
Check belt and chain tension	10			0.08	2.70			0.22	0.0216
Replace belt in the control that activates the transporter chain	4 000	1	155	0.25	2.70			155.67	0.0389
Replace belts in the rolling modifier	4 000	2	155	0.25	2.70			310.66	0.0777
Replace high performance cutting head activator belts	4 000	3	155	0.25	2.70			465.65	0.1164
Replace combined beater-feeder belt	4 000	1	155	0.25	2.70			155.67	0.0389
Check electrical installation (1) and (2)	7 500			0.03	2.70			0.09	0.0000
Check electrical installation	300			0.03	2.70			0.09	0.0003
Clean safety lock on the screw conveyor	750			0.03	2.70			0.09	0.0001
Check safety lock on the screw conveyor (before 300 h)	7 500			0.03	2.70			0.09	0.0000
Check safety lock on the screw conveyor (3)	300			0.03	2.70			0.09	0.0003
Clean the panels of the feeder (before 300 h)	7 500			0.08	2.70			0.22	0.0000
Clean the panels of the feeder (3)	300			0.08	2.70			0.22	0.0007
Check and adjust hydraulic pump chain	10			0.08	2.70			0.22	0.0216
Change hydraulic fluid (before 300 h)	15 000	18	3	0.20	2.70			60.07	0.0040
Change hydraulic fluid (3)	600	18	3	0.20	2.70			60.07	0.1001
Change hydraulic fluid cartridge (before 300 h)	15 000	1	16	0.20	2.70			16.63	0.0011
Change hydraulic fluid cartridge	600	1	16	0.20	2.70			16.63	0.0277
Clean and check automatic cutting height system	10			2.00	2.70			5.40	0.5401
Grease all sites equipped with grease nipples (grease K2k DIN 51825)	10	0.5	6	0.17	2.70			3.20	0.3204
Empty stone collecting tray (for soy and furrow crops)	10			0.08	2.70			0.22	0.0216
6. Threshing and cleaning system									
Adjust concave sleeve (1)	750					0.75	12.00	9.00	0.0120
Check threshing cylinder reducer oil level (before 300 h)	15 000			0.08	2.70			0.22	0.0000
Check threshing cylinder reducer oil level (3)	300			0.08	2.70			0.22	0.0007
Change threshing cylinder reducer oil [oil MIL-L-2105 (API-GL 5), SAE 90]	600	1	3	0.17	2.70			3.76	0.0063
Check sifter revolutions (before 300 h)	15 000			0.05	2.70			0.14	0.0000
Check sifter revolutions (3)	600			0.05	2.70			0.14	0.0002
Check activation of the sieves gear-case and latex bearings (2) *(the Optima model does not have these bearings)*	15 000							0.00	0.0000
Check activation of the sieves gear-case and latex bearings *(the Optima model does not have these bearings)*	300							0.00	0.0000
Check the sifters, their fastness and sieves aperture (before 300 h)	15 000			1.00	2.70			2.70	0.0002
Check the sifters, their fastness and sieves aperture (3)	300			1.00	2.70			2.70	0.0090
Check and, if necessary, stretch grain elevator chain	10			0.08	2.70			0.22	0.0216
Check fastness of unloading tube (2)	15 000			0.08	2.70			0.22	0.0000
Check fastness of unloading tube (3)	600			0.08	2.70			0.22	0.0004
Check tension and condition of belts and chains	10			0.30	2.70			0.81	0.0810

Annex 1 (cont.)

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
Replace belts (labour times are means for the entire set):									
— Engine-beater belt	4 000	1	155	0.30	2.70			155.80	0.0390
— Beater- straw carrier countermarch belts	1 000	2	155	0.30	2.70			310.79	0.3108
— Engine-grain hopper emptying system belt	4 000	1	155	0.30	2.70			155.80	0.0390
— Threshing cylinder controller belt	2 000	1	155	0.30	2.70			155.80	0.0779
— Straw carrier countermarch- sifters countermarch gear-case belts	2 000	2	155	0.30	2.70			310.79	0.1554
— Straw carrier countermarch-rethreshing elevator belt	1 000	1	155	0.30	2.70			155.80	0.1558
— Straw carrier countermarch-fan belt	1 000	1	155	0.30	2.70			155.80	0.1558
— Fan-fan belt	4 000	1	155	0.30	2.70			155.80	0.0390
— Chopper combined belt	1 000	1	155	0.30	2.70			155.80	0.1558
— Engine- chopper activator belts	2 000	1	155	0.30	2.70			155.80	0.0779
— Engine-grain hopper coupling belt	2 000	1	155	0.30	2.70			155.80	0.0779
— Cooling system belt	5 000	1	155	0.30	2.70			155.80	0.0312
Check cylinder-threshing concave	250			0.08	2.70			0.22	0.0009
Change oil in the chaff spreading box	300	1	3	0.17	2.70			3.76	0.0125
Replace lamp in the sifters box	4 000	1	1	0.03	2.70			1.16	0.0003
Replace cylinder beaters	1 200					4.00	12.00	48.00	0.0400
Replace cylinder bearings	1 875	2	42			8.00	12.00	179.97	0.0960
Replace grain hopper conveyor	200	1	219			2.00	12.00	242.52	1.2126
Replace rethreshing elevator conveyors	200	1	154			3.00	12.00	189.74	0.9487
Replace the elevator ball bearings and chain:	750					4.00	12.00	48.00	0.0640
— Ball bearings	750	4	21					83.97	0.1120
— Chain	750	1	135					135.00	0.1800
Replace clean grain conveyor *(includes changing the conveyor, ball bearings and gears)*	1 500					2.50	12.00	30.00	0.0200
— Conveyor	1 500	1	259					259.12	0.1727
— Ball bearings	1 500	2	34					67.18	0.0448
— Gears	1 500	2	51					101.78	0.0679
7. Wheels and brakes									
Check braking system (1)	15 000					1.00	12.00	12.00	0.0008
Check braking system (2)	15 000					1.00	12.00	12.00	0.0008
Check braking system (3)	600					1.00	12.00	12.00	0.0200
Check levels of brake and clutch fluid	10			0.03	2.70			0.09	0.0089
Change brake fluid (fluid DOT 4. DOT 3 or SAE J 170)	2 100	0.35	2	0.50	2.70			2.22	0.0011
Tighten wheel nuts and bolts (2)	15 000			0.25	2.70			0.68	0.0000
Tighten wheel nuts and bolts (3)	600			0.25	2.70			0.68	0.0011
Check clutch play and adjust if necessary (before 300 h)	15 000			0.20	2.70			0.54	0.0000
Check clutch play and adjust if necessary	600			0.20	2.70			0.54	0.0009
Check steering (1) *(check along with hydrostatic transmission)*	15 000							0.00	0.0000
Check steering (2) *(check along with hydrostatic transmission)*	7 500							0.00	0.0000
Check steering (3) *(check along with hydrostatic transmission)*	600							0.00	0.0000
Check and adjust the windage of steered wheels (2) *(check along with the head)*	15 000							0.00	0.0000
Check and adjust the windage of steered wheels (3) *(check along with the head)*	600							0.00	0.0000

Annex 1 (cont.)

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
Check tyre pressure	10			0.30	2.70			0.81	0.0810
Replace front tyres	3 500	2	817	1.50	2.70			1638.93	0.4683
Replace back tyres	1 750	2	136	1.00	2.70			274.40	0.1568
8. Lubrication with grease									
Clean grease nipples before lubricating	10			0.08	2.70			0.22	0.0216
Grease all grease nipples *(includes oil check of all racks)*	10	1.00	6	1.00	2.70			8.21	0.8213
9. Electrical system									
Check batteries (2)	7 500			0.08	2.70			0.22	0.0000
Check batteries	300			0.08	2.70			0.22	0.0007
Change batteries	2 500	2	176	0.20	2.70			351.8	0.1407
Check dashboard indicators and instruments	10			0.03	2.70			0.09	0.0089
Check warning devices work	10			0.03	2.70			0.09	0.0089
Check grain loss control installation	10			0.03	2.70			0.09	0.0089
Check bulbs and thermoemitters (1)	15 000					1.50	12.00	18.00	0.0012
Check bulbs and thermoemitters (2)	7 500					1.50	12.00	18.00	0.0024
Check bulbs and thermoemitters	600					1.50	12.00	18.00	0.0300
Check starter motor (1)	15 000					1.50	12.00	18.00	0.0012
Check starter motor (1)	750					1.50	12.00	18.00	0.0240
Check alternator (1)	15 000					1.00	12.00	12.00	0.0008
Check alternator	750					1.00	12.00	12.00	0.0160
Replace:									
— System check lights (10 bulbs)	7 500	10	1.1	0.17	2.70			11.11	0.0015
— Windscreen wipers	7 500	1	3.6	0.03	2.70			3.64	0.0005
— Full beam headlights	4 000	2	1.1	0.03	2.70			2.22	0.0006
— Dip lights	4 000	2	1.1	0.03	2.70			2.22	0.0006
— Parking lights	4 000	2	1.1	0.03	2.70			2.22	0.0006
— Hopper lights	4 000	2	1.1	0.03	2.70			2.22	0.0006
— Unloading tube lights	4 000	2	1.1	0.03	2.70			2.22	0.0006
— Indicator lights	4 000	2	1.1	0.03	2.70			2.22	0.0006
— Beacon lights	4 000	2	1.1	0.03	2.70			2.22	0.0006
— Cabin light	4 000	1	1.1	0.03	2.70			1.16	0.0003
— Cabin warning lights	4 000	1	1.1	0.03	2.70			1.16	0.0003
— Fuses *(do not ware)*									
— Protection fuse for the electric motor running the cylinder speed changer *(replaced in case of accident)*									
— Bulb for the revolution control system of the separation and cleaning device (bulb 12V/2 sec)	4 000	1	4	0.03	2.70			3.64	0.0009
10. Air conditioning									
Clean condenser cooler	2 000			0.50	2.70			1.35	0.0007
Replace refrigerant FREON 12	2 000	1	20	0.50	2.70			21.74	0.0109
11. Accident prevention									
Check protection systems	10			0.25	2.70			0.68	0.0675
								11.739	9.9706

Purchase value of the wheat/soy platform: $27,200

(1) During the first 20 h. (2) Before 100 h. (3) From 300 h.

Annex 1 (cont.)

Maize platform Mainero 2000 (10 furows at 70 cm)	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
Replace oil in reducers	500	10	2.25	4.0	2.70			33.3	0.0666
Repair reducers	2 000			16	2.70			43.2	0.0216
Ratchets (6 per reducer)	2 000	60	7.20					432	0.2160
Bearings *(not replaced)*									
Repair of roller blades (4 blades per roller)	1 000	80	3.75			10	12	420	0.4200
Replace lifting chain system	1 500			1.50	2.70			4.05	0.0027
Lifting chains *(9 × 25-30 cm chains)*	1 500	2.7	153					412	0.2745
Gears (2 per chain)	1 500	18	61.9					1.115	0.7433
Replace activation chain (step ASA 50; 2 × 2 m chains)	1 000	4	93.9	0.5	2.70			377	0.3769
Replace cross-pieces of cardan joints (2 cardan joints; 4 cross-pieces)	2 500	4	54.7	2.0	2.70			224	0.0897
Replace and adjust spike snapper metal sheets (2 sheets per furrow, incidental)									
Replace metal edges (1 per furrow; incidental)									
								13.061	2.21
Purchase value: $22.862									

Annex 2. CASE Axial Flow 2188 harvester

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
1. 6TA-830 engine (280 CV)									
Check condition and tension of belts	10			0.05	2.70			0.14	0.0135
Check oil level	10			0.10	2.70			0.27	0.0270
Check cooling system	10			0.20	2.70			0.54	0.0540
Clean radiator grill	10			0.20	2.70			0.54	0.0540
Check air restriction indicator	10			0.05	2.70			0.14	0.0135
Clean alternator grill	10			0.05	2.70			0.14	0.0135
Drain water separator filter	50			0.05	2.70			0.14	0.0027
Change engine oil: oil CASE IH no. 1	125	21	2.55	0.20	2.70			54.0	0.4323
Change oil filter	125	1	64.8	0.20	2.70			65.4	0.5230
Clean air filter	200			0.30	2.70			0.81	0.0041
Check/tighten water hose clamps	250			0.20	2.70			0.54	0.0022
Check refrigerant level in radiator	250			0.10	2.70			0.27	0.0011
Change refrigerant fluid filter	250	1	17.0	0.20	2.70			17.5	0.0701
Change fuel line filter (water trap)	500	1	17.5	0.10	2.70			17.8	0.0355
Change the engine main fuel filter	500	1	21.5	1.10	2.70			24.4	0.0489
Change the engine secondary fuel filter	500	1	13.4	2.10	2.70			19.1	0.0382
Change air filter primary element	750	1	102	0.20	2.70			102	0.1365
Change air filter secondary element	750	1	63.9	0.20	2.70			64.5	0.0860
Grease steering wheel supports	750	0.25	5.35	0.20	2.70			1.88	0.0025
Empty diesel tank *(end of harvest)*	750			0.17	2.70			0.45	0.0006
Check valve clearance with engine cold	1 000					0.3	21.00	6.30	0.0063
Check injectors (3)	1 200					1	21.00	21.0	0.0175
Check accelerator cable adjustment	1 500			0.08	2.70			0.22	0.0001
Adjust ignition switch in neutral gear	1 500			0.08	2.70			0.22	0.0001
Replace injectors *(primed and calibrated; Bosch 17 mm)*	2 000	6	147			0.67	21.00	896	0.4478
Change cooling system fluid *(includes conditioner)*	2 000	38	17.7	0.17	2.70			669	0.3343

Annex 2 (cont.)

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
Check injection pump (3)	3 000					1	21.00	21.0	0.0070
Replace alternator belt	3 000	1	17.1	1.00	2.70			19.8	0.0066
Replace turbo-fan belts	3 000	2	51.3	1.50	2.70			107	0.0355
Rectify/Time engine (performed by a third party workshop)	10 000					1	3.000	3.000	0.3000
Complete engine repair									
Specialised labour	10 000					43	21.00	903	0.0903
Spares (including sleeve, piston, rings, pitman, bed metals and axial bearings, set of engine gaskets and sump seals)	10 000	1	1.608					1.608	0.1608
2. Transmission									
Check TDF fluid level	50			0.08	2.70			0.22	0.0043
Check transmission oil level	100			0.08	2.70			0.22	0.0022
Check oil levels in final drives	100			0.17	2.70			0.46	0.0046
Change TDF oil	300	13.2	2.10	0.30	2.70			28.51	0.0950
Change TDF oil filter	300	1.0	13.6	0.20	2.70			14.15	0.0472
Change transmission oil	750	16.2	2.10	0.30	2.70			34.80	0.0464
Change oil in final drives *(2 controls of 13.2 litres*)	750	24.6	2.10	0.30	2.70			52.42	0.0699
Change TDF oil (3)	9 000	13.2	2.10	0.30	2.70			28.51	0.0032
Change TDF oil filter (3)	9 000	1	13.6	0.20	2.70			14.15	0.0016
Change TDF oil (2)	9 900	13.2	2.10	0.30	2.70			28.51	0.0029
Change TDF oil filter (2)	9 900	1	13.6	0.20	2.70			14.15	0.0014
Change TDF oil (oil CASE IH HY-TRAN PLUS) (1)	9 975	13.2	2.10	0.30	2.70			28.51	0.0029
Change TDF oil filter (1)	9 975	1	13.6	0.20	2.70			14.16	0.0014
Complete transmission check *(dismantle, check condition of gears and reassemble)*	10 000					24	21.00	504	0.0504
Complete check of final drives (2 drives)	10 000					9	21.00	189	0.0189
3. Hydraulic system									
Check hydraulic fluid level	10			0.10	2.70			0.27	0.0270
Clean hydraulic breather	100	0.5	0.93	0.17	2.70			0.91	0.0091
Change hydraulic fluid (oil CASE IH HY-TRAN PLUS)	1 000	38	2.10	0.17	2.70			80.2	0.0802
Change system oil filters	1 000	2	2.80	0.17	2.70			6	0.0060
4. Cutting head and transporter duct									
Check blade reducer oil level	10			0.08	2.70			0.22	0.0216
Change blade reducer oil (85-140)	500	2	3.20	0.08	2.70			6.61	0.0132
Adjust feeder switch	750					0.08	21.00	1.68	0.0022
Replace blade (full bar)	1 200	1	1.183	1.5	2.70			1.187	0.9891
Replace platform rudders	1 500	2	346	0.83	2.70			695	0.4635
Replace platform conveyor	5 500	1	1.990	5.0	2.70			2.003	0.3643
Replace blade control belt	2.000	1	130	0.17	2.70			130.46	0.0652
5. Threshing and cleaning system									
Check chain and belt tensions	10			0.3	2.70			0.81	0.0810
Check grease nipples *(when greasing)*	10								
Replace:									
— Rotor control belt	1 000	1	267	0.50	2.70			269	0.2688
— Separator control belt	1 000	1	239	0.17	2.70			240	0.2397
— Auxiliary pump control belt	5 000	1	83.6	0.17	2.70			84	0.0168
— Grain tank unloading control belt	4 000	1	122	0.17	2.70			122	0.0305
— Feeder counter-axle control belt	4 000	1	313	0.17	2.70			313	0.0783

Annex 2 (cont.)

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
— Feeder control belt	4 000	1	277	0.17	2.70			278	0.0695
— Fan control belt	4 000	1	42.0	0.17	2.70			42.5	0.0106
— Lifter control belt	4 000	1	239	0.17	2.70			240	0.0599
— Straw spreading control belt	4 000	1	94	0.17	2.70			94.3	0.0236
— Straw cutting control belt	4 000	1	68.0	0.17	2.70			68.5	0.0171
Grease (lithium grease CASE IH 251H EP) *(total per year):*	750	15	5.35					80.2	0.1069
— Cam supports of the rotor drive	10			0.05	2.70			0.14	0.0135
— Rotor pulley	10			0.05	2.70			0.14	0.0135
— Unloading tube pivot	10			0.05	2.70			0.14	0.0135
— Sieve of chaff suspender (right and left sides)	10			0.10	2.70			0.27	0.0270
— Support of the residue feeder conveyor	10			0.05	2.70			0.14	0.0135
— Auxiliary pump tension lever	50			0.06	2.70			0.16	0.0032
— Front rotor speed controller	50			0.06	2.70			0.16	0.0032
— Back rotor speed controller	50			0.06	2.70			0.16	0.0032
— Rotor driving pulley	50			0.06	2.70			0.16	0.0032
— Unloader control tension lever	50			0.06	2.70			0.16	0.0032
— Straw cutter tension lever	50			0.06	2.70			0.16	0.0032
— Straw spreader tension lever	50			0.06	2.70			0.16	0.0032
— Fan pulley	50			0.06	2.70			0.16	0.0032
— Cleaning tightening arm	50			0.06	2.70			0.16	0.0032
— Feeder tension lever	50			0.06	2.70			0.16	0.0032
— Header tension lever	50			0.06	2.70			0.16	0.0032
— Fan tightening arm	50			0.06	2.70			0.16	0.0032
— Transverse axis	100			0.07	2.70			0.19	0.0019
— Unloading sleeve axis	100			0.07	2.70			0.19	0.0019
— Exterior drive wheel coupling	100			0.07	2.70			0.19	0.0019
— Inner drive wheel coupling	100			0.07	2.70			0.19	0.0019
— Axle support of the feeder reverser	100			0.07	2.70			0.19	0.0019
— Free gear with reversing stone collector	100			0.07	2.70			0.19	0.0019
— Tension lever with reversing stone collector	100			0.07	2.70			0.19	0.0019
— Feeder screw conveyor axis of the residue outlet	100			0.07	2.70			0.19	0.0019
— Slipping clutch of the elevator	100			0.07	2.70			0.19	0.0019
— Elevator inner axis support	100			0.07	2.70			0.19	0.0019
— Elevator outer axis support	100			0.07	2.70			0.19	0.0019
— Residue feeder screw conveyor axis support	100			0.07	2.70			0.19	0.0019
— Fan case support	100			0.07	2.70			0.19	0.0019
— Outer self-driving wheel coupler	100			0.07	2.70			0.19	0.0019
— Inner self-driving wheel coupler	100			0.07	2.70			0.19	0.0019
— Inclined feed screw conveyor lower support	500			0.10	2.70			0.27	0.0005
— Rotor front support	500			0.10	2.70			0.27	0.0005
— Hydraulic pump control	500			0.10	2.70			0.27	0.0005
— Clean grain screw conveyor feeder axis	500			0.10	2.70			0.27	0.0005
— Slipping clutch of the agitator axis control	500			0.10	2.70			0.27	0.0005
— Cleaning feeder and fan gear case	500			0.10	2.70			0.27	0.0005
— Fan adjustable pulley	500			0.10	2.70			0.27	0.0005
— Chains	10			0.05	2.70			0.14	0.0135
Clean fan control belt	750			0.17	2.70			0.46	0.0006
Clean fan counteraxis belt	750			0.17	2.70			0.46	0.0006
Adjust elevator safety clutch	750			0.10	2.70			0.27	0.0004
Adjust gear of the feeder conveyor bed control	750			0.50	2.70			1.35	0.0018
Clean straw spreader	100			0.33	2.70			0.89	0.0089
Adjust intermediate axis limit switch	750			0.10	2.70			0.27	0.0004

Annex 2 (cont.)

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
Replace mobile wheel blade reinforcement/change wearing plate *(labour considered along with that of unloading conveyors)*	750	1	50.0					50.0	0.0667
Adjust concave *(automatically from the cabin)*	750							0.00	0.0000
Replace rotor grinders	2 000	64	12.0	1	2.70			768	0.3840
Check feeder gear case and cleaning fan oil	50			0.17	2.70			0.46	0.0092
Change feeder gear case and cleaning fan oil	500	2.6	2.10	0.17	2.70			5.9	0.0118
Check lower unloader gear case oil	50			0.05	2.70			0.14	0.0027
Change lower unloader gear case oil	500	0.86	2.10	0.17	2.70			2.26	0.0045
Check rotor gear case oil	50			0.05	2.70			0.14	0.0027
Change rotor gear case oil	500	3.8	2.10	0.17	2.70			8.4	0.0169
Check straw cutter gear case oil	50			0.05	2.70			0.14	0.0027
Change straw cutter gear case oil	500	3.1	2.10	0.17	2.70			7.0	0.0139
Replace axle guards of the grain pan	1 500	6	7.97	0.17	2.70			48.3	0.0322
Replace rotor point bearings	5 000	2	115			3	21.00	292	0.0584
Replace conveyors:									
Conveyor bed conveyors	2 500	5	71.6			5	21.00	463	0.1853
Conveyor bed bearings *(along with conveyors)*	2 500	5	42.8					214	0.0856
Wooden blocks of the conveyor bed	1 250	5	3.00			1.5	21.00	46.5	0.0372
Clean grain conveyor	1 800	1	796			2	21.00	838	0.4655
Clean grain conveyor bearings *(change with conveyor)*	1 800	2	42.8					85.6	0.0475
Rethreshing conveyor	2 750	1	588			2	21.00	630	0.2292
Rethreshing conveyor bearings *(along with conveyor)*	2 750	2	42.8					85.6	0.0311
Inclined supply conveyor	2 750	1	1.194			1.5	21.00	1.225	0.4456
Inclined supply conveyor bearings *(along with conveyor)*	2 750	2	1.605					3.209	1.1670
Hopper conveyors	2 750	2	637			7	21.00	1.421	0.5166
Hopper conveyor bearings *(along with conveyor)*	2 750	2	42.8					85.6	0.0311
Elevating vertical conveyor	1 500	1	716			5	21.00	821	0.5476
Change oil in square cases *(2 × 1.5 litre cases)*	1 000	3	4.00	0.25	2.70			12.7	0.0127
Unloading tube conveyors *(linked by a hexagonal joint and bearing)*	1 500					4	21.00	84.0	0.0560
Back horizontal conveyor	1 500	1	637					637	0.4245
Front conveyor	1 500	1	637					637	0.4245
Change square case oil	1 000	1.5	4.00	0.25	2.70			6.67	0.0067
Unloading screw conveyor square case bearings *(labour considered along with conveyor replacement)*	1 500	2	42.8					85.6	0.0571
6. Wheels, brakes and steering									
Check tyre pressure	50			0.30	2.70			0.81	0.0162
Adjust brake pedal	4 000			0.08	2.70			0.22	0.0001
Replace front tyres (30.5 L 32-10 screens)	7 000	2	1.727	1.50	2.70			3.458	0.4940
Replace back tyres (18.4-26-10 screens)	1 800	2	632	1.00	2.70			1.266	0.7034
Adjust wheel nuts and bolts	1 800			0.25	2.70			0.68	0.0004
Grease:									
— Steering axis (front and back pivots)	50	0.20	4.60	0.08	2.70			1.14	0.0227
— Power guide axis *(300 g grease):*	50	0.30	4.60					1.38	0.0276
• Ends of tensing bar (right and left)	50			0.04	2.70			0.11	0.0022
• Steering roller ball-and-sicket joints (right and left)	50			0.04	2.70			0.11	0.0022
• Steering hinge-left upper and lower parts	50			0.04	2.70			0.11	0.0022
• Steering hinge-right upper and lower parts	50			0.04	2.70			0.11	0.0022
— Adjustable control axis *(absent in this model):*	50	0.20	4.60						
• Tensing rod end (left and right)	50			0.04	2.70				
• Left and right steering roller ball-and-sicket joints	50			0.04	2.70				
• Right and left steering hinge	50			0.04	2.70				
— Left and right wheel support	750			0.04	2.70				

Annex 2 (cont.)

Maintenance and repair items	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
8. Electrical system									
Check electrolyte levels in batteries	100	1	0.50	0.08	2.70			0.71	0.0071
Change batteries	2 500	2	180	0.20	2.70			361	0.1445
Check dashboard indicators and instruments	10			0.03	2.70			0.09	0.0089
Check warning devices work	10			0.03	2.70			0.09	0.0089
Replace:									
— Front headlights:									
• Full beam cabin lights	4 000	3	20.4	0.13	2.70			61.5	0.0154
• Dip cabin lights	4 000	3	15.3	0.13	2.70			46.2	0.0115
• Headlights under cabin	4 000	2	17.4	0.08	2.70			34.9	0.0087
• Side lights	4 000	2	26.5	0.08	2.70			53.2	0.0133
• After-cutting lights	4 000	2	17.4	0.08	2.70			34.9	0.0087
• Back floodlight	4 000	1	52.1	0.08	2.70			52.3	0.0131
• Tail lights (parking and turning)	4 000	2	42.8	0.08	2.70			85.8	0.0215
— Dashboard lights:									
• Indicator background lights	4 000	2	1.30	0.10	2.70			2.9	0.0007
• Dashboard background lights	4 000	1	1.30	0.10	2.70			1.6	0.0004
• Grain sweeping monitoring lights	4 000	2	1.30	0.10	2.70			2.9	0.0007
• Indicator lights	4 000	2	1.30	0.17	2.70			3.1	0.0008
• Grain hopper light	4 000	1	20.4	0.08	2.70			20.6	0.0051
• Unloading tube light	4 000	1	14.8	0.08	2.70			15.0	0.0037
Replace windscreen wiper blade	7 500	1	4.12	0.05	2.70			4.26	0.0006
9. Air conditioning, heating and ventilation									
Clean cabin air filter	20			0.17	2.70			0.46	0.0230
Change cabin air filter	2 000	1	97	0.17	2.70			97.8	0.0489
Replace air conditioning gas	4 000							150	0.0375
								32.056	13.573

Purchase value of the wheat/soy platform: $27,200

Annex 2 (cont.)

Maize platform (8 furrows at 70 cm) CASE 1083	Periodicity [h]	Materials		General labour		Specialised labour		Total [$]	Mean [$ h^{-1}]
		[quant.]	[$]	[h]	[$ h^{-1}]	[h]	[$ h^{-1}]		
Check oil level of the roller gear-cases (8 cases)	10			0.40	2.68			1.073	0.1073
Replace oil in the roller gear-cases (oil 85-140)	1 000	12	2.00	3.00	2.68			32.05	0.0320
Replace rollers (2 per furrow) *(do not need changing)*		16	82.7	8.00	2.68				
Replace roller ends *(labour included with that of rollers)*	1 750	16	71.0					1.136	0.6491
Replace roller blades (4 blades per roller)	900	64	23.0	10.0	2.68			1.498	1.6639
Replace roller counterblades (1 blade per roller)	900	16	17.0	4.00	2.68			283	0.3141
Replace roller control system	2 000			2.50	2.68			6.708	0.0034
Control chains (1 per roller)	2 000	16	45.0					720	0.3600
Back gear drive (1 per roller)	2 000	16	28.0					448	0.2240
Front gear- tensor-bearing complex (1 per roller)	2 000	16	17.0					272.0	0.1360
Repair platform conveyor *(does not need changing)*		5.5	40.0			3.0	30		
Replace reducer and conveyor drive chain (10 metres)	400	10	18.0	0.50	2.68			181.3	0.4534
								4.577	3.943

Purchase value: $25,250