

## *The proposition of factors for analysis of the maintenance of agricultural tractors from a systematic bibliographic review*

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### **ABSTRACT**

*The maintenance of agricultural tractors can be understood as the set of procedures that seek to keep the equipment in the best working conditions. However, carrying out adequate planning that can help optimize the maintenance of agricultural tractors is a complex task. The article consists of identifying and presenting a proposal of analysis factors for the maintenance of agricultural tractors, as well as their technical characteristics and modes of operation. In methodological terms, a Systematic Bibliographic Review was applied on maintenance and planning for agricultural tractors in two international databases. The research is classified as descriptive and comparative, of an exploratory nature. As a result, the study contributed to the information gap regarding the maintenance of agricultural tractors. In addition, we identified the main factors that must be analyzed to keep the equipment in the best operating conditions and that are responsible for increasing its useful life and avoiding future problems. The maintenance factor, which includes checking the level and oil change of the front axle, is characterized as the most important analysis procedure.*

*Keywords: maintenance, agricultural tractors, the proposal of factors, best operating conditions.*

**Editor Responsável:** Prof.  
Dr. Hermes Moretti Ribeiro da  
Silva

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SILVEIRA, F.; MACHADO, F.M.; AMARAL, F.G.; SANTOS, B.M.; RODRIGUES, P.C.C. The proposition of factors for analysis of the maintenance of agricultural tractors from a systematic bibliographic review. **GEPROS. Gestão da Produção, Operações e Sistemas**, v. 15, n. 1, p. 151 - 170, 2020.

**DOI:** 10.15675/gepros.v15i1.2405

## 1. INTRODUCTION

A the agricultural tractor is the main source of power in the rural environment (MÁRQUEZ, 2012) necessary for the development and technological advancement of agricultural food production systems (CAVALLO *et al.*, 2014; RESITOGLU; ALTINISIK; KESKIN, 2015) and the use of alternative sources of renewable energies (MAHMUDUL *et al.*, 2017) such as Biodiesel, Natural Gas, Vegetable Oil, Ethanol and Diesel Oil with Hydrated Ethanol (ESTRADA *et al.*, 2016, WEI; GENG; FARIAS *et al.*, 2017; GENG *et al.*, 2017). The correct use of the tractor can generate significant savings in energy consumption, lower operating costs and higher profits for the owner (LIPS; BUROSE, 2012; AFSHARNIA *et al.*, 2013; AL-SUHAIBANI; WAHBY, 2017).

One of the tools for the correct use of agricultural tractors is expressed through the management of maintenance operations (BOCHTIS *et al.*, 2014). Maintenance can be understood as the set of operations that are carried out to maintain and maintain agricultural mechanization under the best conditions for use (LAMBRECHT *et al.*, 2015). However, the maintenance must take place in the programmer period and in an appropriate way, in order to guarantee better utilization of the machine and to maximize the useful life (AFSHARNIA *et al.*, 2013). In addition, the management of traditional methods of tractor maintenance must be viewed differently than the procedures performed on agricultural machines in general (BOCHTIS *et al.*, 2014) because tractors are subject to a greater impact on the environment and inherent to the different risks present in the entire production process of agricultural commodities (BOCHTIS *et al.*, 2014; LORENCOWICZ ; UZIAK, 2015).

Due to the high technology embedded in agricultural tractors, it is necessary to train the operators through training, as well as provide information support to follow the technological evolution of hydraulic and mechanical components that are subject to functional problems and that require special attention to operationalize an adequate maintenance (RALPH *et al.*, 2012). Other operational tasks related to maintenance management should also be analyzed (ASAE EP496.3, 2006), as the scheduling of the various tasks that must be performed during the maintenance process and that should be predicted considering the work demand, priorities and crop requirements (ASAE S495.1, 2005). Therefore, component

change planning and expected system performance should be designed to ensure the best possible tractor functionality (ASAE S495.1, 2005).

Agriculture is one of the main sectors responsible for the Brazilian economy. In 2013, agriculture accounted for 5% of global agricultural production, standing out as the fourth largest share (China, USA, India and Brazil) and 6% of global agricultural exports (USA, Netherlands and Brazil). In order to develop agriculture, it is necessary to modernize agricultural machinery, especially in relation to tractors, which promote the transformation of the technical base, increase productivity and consolidate industrial complexes. Therefore, it is important to identify indicators that contribute to a decision making regarding the requirements that should be considered in the maintenance of agricultural tractors (MUELLER; MUELLER, 2016; GHINOI *et al.*, 2018).

To fill the identified gap regarding the scarcity of studies of the process of tractor maintenance, the article aims to present a proposal of analysis factors for the maintenance of agricultural tractors. It is noteworthy that despite the proposition of the factors found in the literature on analysis for the maintenance of agricultural tractors, it is not the objective of the research to rigorously define the semantics and syntax of the methods. The results found in this study contribute to new perspectives that must be adopted and that reflect in the better performance of the agricultural tractor, facilitating the practical application of the same ones.

The paper is structured into five different sections, in addition to this introduction. Section 2 deals with the Brazilian market of agricultural tractors and its main aspects. Subsequently, the importance of maintaining tractors to increase their useful life is contextualized. Section 3 presents the methodological approach used in the study. In section 4 the results are shown. Section 5 presents the conclusions of the research, the limitations found and the proposals for future work. Finally, section 6 presents the references used in the research.

## 2. LITERATURE REVIEW

### 2.1 Brazilian market of agricultural tractors

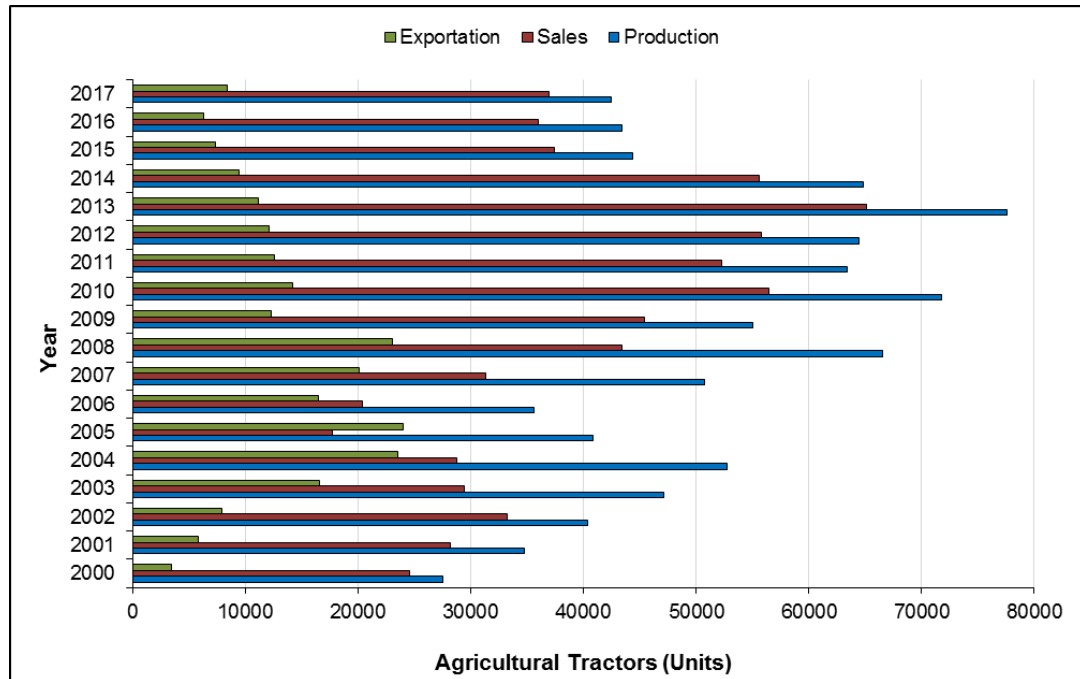
In Brazil, agricultural credit policy provides rural producers with programs that provide capital to finance, invest and commercialize. The emphasis is on agricultural investment credit, which may be from public or private sources, and is enjoyed to increase

farmers' productivity through land acquisitions, construction and warehouse reforms and purchases of agricultural machinery (BARICELO, 2015).

One of the lines of credit for investment in rural activities is the Modernization Program of the Agricultural Tractors Fleet and Associated Implements and Harvesters (MODERFROTA in portuguese). This program aims to reduce the losses that occur in the field because the Brazilian agricultural machinery park is inefficient and obsolete (MAPA, 2015). With financial agents such as MODERFROTA, rural producers seek to invest in new agricultural tractors that can provide better productivity and, at the same time, foster the productive chain of agricultural machinery in the country (MAPA, 2015; ANFAVEA, 2018). For the financing of the MADERFROTA program, the Brazilian government made available an amount of 3,650 million reais for the harvest of 2015-2016. In the state of São Paulo (SP), there is the Pro-Tractor Program, which also offers the rural producer of São Paulo the opportunity to purchase a tractor with a financing with no interest rate (MAPA, 2015). The MADERFROTA and the Pro-Tractor programs are contributing to raising the rate of the fleet of agricultural tractors and ensure greater productivity.

It can be seen in Figure 1 the behavior of production, national/international domestic sales and export of agricultural tractors, the main product of the farm machinery market in Brazil, between 2000 and 2017. It is noted that the tractor market has decreased in recent years, in domestic sales and in the years 2013, 2014, 2015 and 2016. However, there was a small increase in exports and sales in 2017. Vian *et al.* (2013), describe that competitiveness in the Brazilian market for agricultural tractors takes into account the instability of the country, its constant changes in agricultural policy (suspension of credits and/or financing), the price paid for agricultural commodities and foreign currency fluctuations (dollar). In addition, factors such as the reduction of equipment prices, the increase in product quality, ease of maintenance and differentiation of innovations are issues that interfere with the expansion powers of the agricultural tractors market in Brazil (SILVEIRA; SIERRA, 2010; VIAN *et al.*, 2013; FARIAS *et al.*, 2017; ANFAVEA, 2018).

**Figure 1** - Participation of agricultural tractors in the Brazilian market between 2000 and 2017.



Source: Elaborated by the authors based on data from (ANFAVEA, 2018).

According to Bilski (2013), there are approximately 29 million agricultural tractors in the world. The United States of America accounts for 17% of agricultural tractor units, followed by India with 9%. Brazil accounts for about 3% of the world fleet (SILVA; VIAN, 2017). The Brazilian market of agricultural tractors occupies the 10th position in the ranking of exports. For grain harvesters the situation is slightly better, it is in the 5th position (SILVA; VIAN, 2017). Due to the significant participation in the international context, it is important to identify the factors that can contribute to increasing the durability of agricultural tractors. For Mattetti, Molari and Sereni (2017), durability is about the ability of a machine to maintain functionality during its planned life under recommended conditions and by increasing its use of its respective prescribed levels of maintenance.

## 2.2 Agricultural tractor maintenance

According to the Brazilian technical standard on reliability and maintainability (ABNT, 1994), maintenance is generally defined as a combination of all technical actions aimed at maintaining or restoring an item so that it can perform the function again for which it

was designed. Thus, it is sought to increase the useful life of machines and equipment through maintenance planning (POPPE et al., 2017), so that the efforts are directed only at the actions with more chances of obtaining a good result with low effort (SILVA; SELLITTO, 2014). For Cooke (2003), the rational use of machines and equipment, in this case, depends on a well-articulated strategy within the organization for effective maintenance, insofar as the importance of the reliability of these assets can be critical but enhanced by good procedures of maintenance.

The maintenance of agricultural tractors can be understood as the set of procedures that seek to keep the equipment in the best working conditions, providing an increase in its useful life, avoiding future problems and eliminating the observed ones in order to guarantee a greater safety in the work (PIACENTINI *et al.*, 2012). Significant operating costs resulting from the continued use of agricultural tractors are related to repair and maintenance costs. For Marques Andersson et al. (2015), the cost of mechanization can reach 40% of the cost of production, denoting that maintenance, if well planned, can contribute to reducing this percentage. Peloia and Milan (2010), complement that the agricultural mechanization, represents a factor of great relevance for the competitiveness in terms of costs, becoming inferior only to the possession of the earth. Simões and Silva (2012), affirm that in terms of the potential to reduce production costs, actions under mechanization can be considered as the main factor in the analysis process.

All the existing maintenance techniques aim to reestablish the operation of the equipment, as well as seek to significantly reduce the operational cost (BAYDIA *et al.*, 2016), and the most frequently encountered both in the literature and in practice are about corrective maintenance or not (BAYDIA *et al.*, 2016; POPPE *et al.*, 2017) and predictive maintenance, which occurs as a function of a detective follow-up or a managerial decision to operate until the moment of shutdown to set up the equipment, while that the unplanned occurs when the equipment is compromised (KARDEC, 2009; MÁRQUEZ, 2012). Preventive or planned maintenance should occur from a maintenance stop schedule. Preventive and predictive maintenance means acting before failure occurs, and the key to maximizing availability and efficiency can be considered for farm machine maintenance, reducing unplanned costs with unplanned or corrective maintenance (AHMAD; KAMARUDDIN, 2017).

For Fontes *et al.* (1997), maintenance follows the technical-industrial development of mankind since the nineteenth century which, together with industrial mechanization, are

responsible for the emergence of corrective maintenance. According to the author, maintenance was of secondary importance and its execution was carried out by the workers themselves. Over the years, from the evolution and progress of technologies on the machines, both preventive and corrective maintenance became indispensable for the correct operation of the mechanized activities and then it was necessary to develop teams and train specific professionals for such tasks.

For Spohr (2008), the maintenance of agricultural tractors, as well as agricultural mechanization in general, seek to maintain optimal conditions of operation and better performance to match the high investment cost that they present in the acquisition process. Through lubrication, overhauls, and protection against damaging factors that are present in the air, soil and plants, it is also possible to obtain improvements in the performance of agricultural tractors. Lambrecht *et al.* (2015) describe that an alternative is to follow the guidelines that are recommended by the manufacturers so that the tractors maintain good conditions of operation. To do this, operators must have access to the owner's manual and the maintenance scheduling guidelines proposed by the manufacturer.

It is perceived that planning a series of factors to assist in optimizing the maintenance of agricultural tractors is a complex task. In the literature, it is possible to find different researchers that aim to facilitate the decision making of tractor purchases (MEHTA; SINGH; SELVAN, 2011; AMINI; ASSODAR, 2016; GARCÍA-ALCARAZ *et al.*, 2016). However, for the management of agricultural tractors, with emphasis on the complete optimization of their maintenance, there is a lack of studies (POOZESH *et al.*, 2012; SOPEGNO *et al.*, 2016; AL-SUHAIBANI; WAHBY, 2017). Thus, the research seeks to contribute to a detailed level a variety of maintenance factors for agricultural tractors, simplifying the different parts as a whole.

### 3. METHOD

The research was focused on the interface between the maintenance area in agricultural tractors and the operational part in agriculture. Then, the method of Systematic Bibliographic Review (RBS) was selected to carry out the research. The RBS methodology uses as a data source the existing literature on a given theme, selects and evaluates contributions, analyzes and synthesizes data (BIOLCHINI *et al.*, 2005; CONFORTO; AMARAL; SILVA, 2011). In addition, it describes the evidence in order to allow conclusions

about what already exists, as well as what is not known about the subject matter (DENYER; TRANFIELD, 2009). The analysis of the research is characterized as theoretical-conceptual and seeks to present the main studies that explain the maintenance of agricultural tractors in order to identify and analyze which factors may affect their useful life (LOPES; CARVALHO, 2012).

The scope of the review of the literature includes articles published in journals that deal with the maintenance of agricultural tractors and that seek to direct parameters that are important to carry out an adequate and effective agricultural planning regarding the performance of different agricultural operations. The *Science Direct* and *Scopus* databases were selected because of their circumscriptions and importance in the academic environment, as well as being related to the areas of knowledge considered in the research (agricultural machinery, maintenance, tractors, agrarian planning for mechanizations and related areas). To perform the advanced searches in the databases, it was necessary to make use of logical operators. Subsequently, it was necessary to establish the keywords (without quotes and without refinement by area of knowledge) to be used in the theoretical survey in the selected databases.

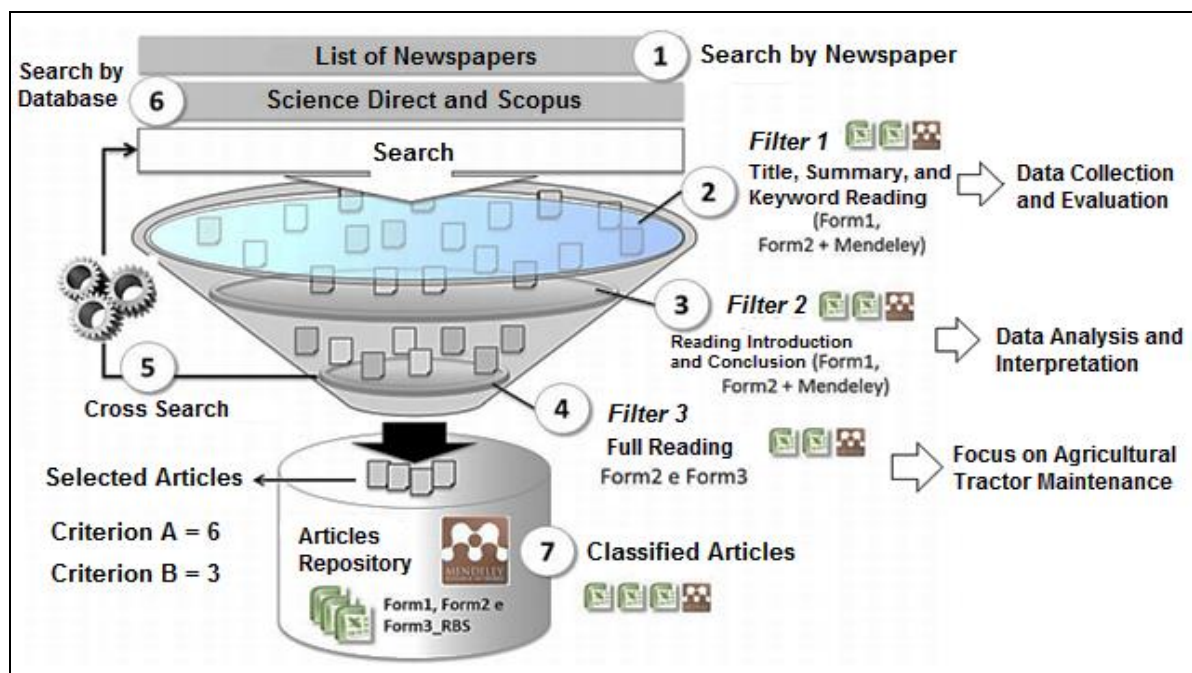
The procedure used was "*Boolean*" (CARAYON *et al.*, 2015), correlating two criteria according to the following keywords: i) **A** - *maintenance on agricultural tractors*; e ii) **B** - *maintenance factors in agricultural*. In the research were considered publications between the years of 2000 to 2018 that presented the terms required in their abstracts. Only papers written in English and "*article*" and "*review*" documents were selected, disregarding books and book chapters. For the files available in full, it was necessary to perform snowballing (CLEMENTS *et al.*, 2017) to ensure that other relevant works were not detected in the original research. After the filtering application, **246** articles were identified in the databases (**A** → (170) + **B** → (76)).

We excluded 167 articles that were not related to the research topic and to consider in their structuring agricultural machines and not specifically agricultural tractors or else to emphasize maintenance in tractors resulting from the operator's ability, climatic conditions, maintenance policy, among other factors. Subsequently, the abstracts and keywords that included the established terms were evaluated and 43 other works were excluded, which did not help to identify the maintenance practices or areas in which costs and repairs can be minimized. Another filtering was carried out with emphasis on the introduction and



conclusion of the articles, being excluded another 27 works. Finally, a complete reading of the articles resulting from the filter 2 was carried out and 9 research papers (**A** → (6) + **B** → (3)). To facilitate the understanding of the steps adopted in the methodological flow of RBS, Figure 2 was developed. The analysis was done using the Mendeley software and it was necessary to use Microsoft Office® Excel 2013 for data tabulation.

**Figure 2** - Structure of the RBS methodological flow.



Source: Adapted from (CONFORTO; AMARAL; SILVA, 2011).

The research selected different approaches to maintenance in agricultural tractors in order to demonstrate a set of variables that are used concomitantly in academic research and the business sector. It is important to stress that tractors are an essential source of energy in agriculture, where they are used in most agricultural operations throughout the year (AL-SUHAIBANI; WAHBY, 2017). Therefore, identifying the key factors that should be considered in agricultural tractor maintenance makes it useful for farmers to prepare spare parts requirements and be ready for any adverse situation in the field. In addition, it is important for the industry, while factor definition assists in the development of adequate maintenance plans. According to Khoub *et al.* (2008), a set of factors for the maintenance of

agricultural tractors can help in the decision of the time of replacement of parts that can present damages and with relation in the progress and evolution of their projects.

#### 4. RESULTS AND DISCUSSIONS

The information from 9 articles dealing specifically with the maintenance of agricultural tractors was evaluated. The search criterion A presented the highest number of publications among the articles identified. In Table 1 are the selected researchers after performing RBS. It should be noted that the indicative corresponds to the order of the articles that were found to facilitate the description of the results. No publications were found that deal with the maintenance of autonomous agricultural tractors. For Zhang and Noguchi (2017), autonomous tractors will be adopted in the next years in "modern" agriculture, since they reduce working time and improve the efficiency in the productive process of commodities. According to Zhang, Yang and Noguchi (2013), the performance of the autonomous tractors is better than the results of an experienced operator. Thus, it is noticed that a new information gap on the subject of maintenance in agricultural tractors (autonomous) is developing.

**Table 1** - Researches that consider maintenance in agricultural tractors.

Authors / Year	Title	Journal	Objective	Criterion	Indicative
Öhman et al. (2004)	Remote maintenance of agricultural machines	IFAC Proceedings Volumes	Develop a prototype of an open, generic and configurable automation platform for agricultural machines to assist in faults and remote maintenance over mobile networks.	A	I
Rohani, Abbaspour-Fard and Abdollahpour (2011)	Prediction of tractor repair and maintenance costs using Artificial Neural Network	Expert Systems with Applications	To evaluate the costs of repair and maintenance of tractors using Artificial Neural Network.	A	II
Lips and Burose (2012)	Repair and Maintenance Costs for Agricultural Machines	International Journal of Agricultural Management	Present the repair and maintenance factors to indicate accumulated repair and maintenance costs for agricultural machinery.	B	III

Afsharnia et al. (2013)	Failure rate analysis of four agricultural tractor models in southern Iran	Agricultural Engineering International: CIGR Journal	Predict the failure rate of the tractors from a regression model and verify the factors that affect the rate.	B	IV
Afsharnia, Asoodar and Abdesha hi (2014)	The Effect of Failure Rate on Repair and Maintenance Costs of Four Agricultural Tractor Models	International Journal of Agricultural and Biosystems Engineering	To uncover specific issues associated with tractor maintenance costs by investigating the frequency of these variables in field operations for different tractor models based on their failure rate.	B	V
Lorenco wicz and Uziak (2015)	Repair Cost of Tractors and Agricultural Machines in Family Farms Agricultural Equipment in Greece: Farm Machinery Management in the Era of Economic Crisis	Agriculture and Agricultural Science Procedia	Present problems related to the calculation of repair costs of tractors and agricultural machinery.	A	VI
Papageorgiou (2015)	Repair Cost of Tractors and Agricultural Machines in Family Farms Agricultural Equipment in Greece: Farm Machinery Management in the Era of Economic Crisis	Agriculture and Agricultural Science Procedia	Examine the management of agricultural machinery in Greece during the economic crisis, a period of market volatility and the need to reduce production costs.	A	VII
Sopegno et al. (2016)	A web mobile application for agricultural machinery cost analysis	Computers and Electronics in Agriculture	Develop an easy-to-use mobile application called "AMACA" (Application for Agricultural Machine Cost Analysis) to determine the cost of machinery in different field operations and make it available through a mobile web application.	A	VIII
Al-Suhaibani and Wahby (2017)	Farm tractors breakdown classification	Journal of the Saudi Society of Agricultural Sciences	To classify the repairs or maintenances based on order of service of 40 tractors.	A	IX

Source: Authors (2018).

In Table 2 it is possible to identify an elaborated synthesis on each of the analysis procedures of the maintenance factors identified in the literature. In order to prioritize the factors that are directly responsible for increasing the useful life of agricultural tractors based on scientific studies, it was necessary to develop the criterion of necessity with respect to the indicative factor. The indicative includes the number of articles dealing with the specific maintenance factor.

Therefore, it was necessary to establish three priority factors: a) Low (**Green**); b) Average (**Yellow**); and c) High (**Red**). The Low requirement refers to articles that deal with only one maintenance factor. The average need was adopted in situations that considered in their development of two different articles on maintenance factors. Finally, the High requirement includes the indications with three or more citations of scientific articles.

**Table 2** - Proposal of factors for analysis of the maintenance of agricultural tractors.

Maintenance Factors	Analysis Procedure	Indicative	Necessary
1. Check the operation of the electrical system	The perfect functioning of the headlights, signal lamps and the panel, alternator, and battery (electrolytes, sigh, level and terminals) ensure operator efficiency and safety during agricultural operations.	II; III; IX	High
2. Check fan belt tension	The free play of this belt causes motor overheating due to refrigeration deficiency. The tractor that uses this belt to move the alternator may have problems recharging the battery.	VIII; IX	Medium
3. Check radiator water level	The absence of water in the cooling system causes motor overheating causing premature wear and consequent.	I; IV; V	High
4. Check oil level and engine oil level and change	Oil below the level, or contaminated, cause's premature wear and overheating. Above the level, causes the increased internal pressure of the engine compromising the service life of joints and seals.	III; VI; VIII	High
5. Check transmission oil level and change	The low level of this oil, or contamination, causes poor lubrication, resulting in premature wear of the gears and other components.	II; VIII	Medium
6. Check oil level and oil filter and hydraulic system filter	The low level of this oil, or contamination, causes premature wear and loss of power from the hydraulic lift system and remote control (on some tractor models).	VIII; IX	Medium
7. Check pump oil level and change	The low level of this oil, or contamination, causes poor lubrication of the injection pump, leading to premature wear and loss of efficiency (in some tractor models).	VIII	Low
8. Check level and oil change and power steering filter	The low level of this oil, or contamination, causes hard steering making it difficult to drive the tractor (in some tractor models).	I; V	Medium
9. Check the oil level of the wheel hubs	The low level of this oil, or contamination, causes poor lubrication, resulting in premature wear of the gear units, reducing their useful life (on some tractor models).	III; IV	Medium
10. Check front axle oil level and change (differential)	The low level of this oil, or contamination, causes poor lubrication, resulting in premature wear, reducing its useful life (on some tractor models).	III; VI; VIII; IX	High
11. Check rear end gear unit oil level and oil change	The low level of this oil, or contamination, causes poor lubrication, resulting in premature wear of the gears, reducing their useful life.	III; IX	Medium
12. Clean and replace air filter	The air filtration system is in perfect condition to prevent airborne abrasive particles from being allowed into the engine.	IV; VII	Medium

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element or oil change	thus preventing premature wear.		
13. Clean filter at injection pump inlet	This filter prevents impurities present in the fuel from entering the feed system. Contamination of fuel results in loss of tractor efficiency.	VI; IX	Medium
14. Clear sighs	The clogging of the sigh of some sector causes a deficiency of ventilation, overheating and excess of pressure.	III	Low
15. Clean fuel tank	The accumulation of impurities in the tank causes an overload of the filter system, affecting the power and operation of the engine.	I; IX	Medium
16. Calibrating tires	Correct tire calibration increases tire life and provides better grip by reducing excessive skating and fuel wear.	IX	Low
17. Calibrate nozzles and injection pump	Deregulated nozzles and injection pump result in loss of engine power and high fuel consumption.	V; VII	Medium
18. Change fuel filter	Dirty or clogged filter causes malfunction of the power supply system resulting in loss of efficiency of the motor.	IV; VI	Medium
19. Draining of pre-filter or settler and fuel filter	Eliminate water and impurities from the fuel system. These elements can cause clogging and corrosion of the feed system components, causing malfunction and loss of engine efficiency.	V; VII	Medium
20. Sangria in filters and injection pump	Eliminate air from the feed system. The air in the system causes a malfunction of the engine and may even interrupt its operation.	V	Low
21. Grease grease pins	Avoid premature wear of moving and scraping tractor parts that require grease.	I; IX	Medium
22. A fuel tank at the end of the day	Empty tank favors the condensation of the air present in its interior resulting in the contamination of the oil with water. Water can cause engine malfunction in addition to corrosion of the power system.	VIII; IX	Medium
23. Re-tighten nuts	Normal tractor work causes vibration of parts to loosen nuts and bolts. Replenishment prevents slack and loss of parts.	I; III; IX	High
24. Regular brake pedals	Excessive play causes brake failure and difficulty in operation of the tractor. The absence of this clearance causes premature wear of the braking system, including tarpaulins and drum, and accident risks.	I; IX	Medium
25. Regular clutch pedal	Excessive play causes difficulty in the engagement of gears, which can damage it. The absence of this clearance causes premature wear of the clutch collar.	I; VI	Medium

Source: Authors (2018).

By means of the maintenance factors identified in the literature, it can be verified that the level and exchange of oil of the front axle (differential) presented a high need for maintenance (LIPS; BUROSE, 2012; LORENCOWICZ; UZIAK, 2015; SOPEGNO *et al.*, 2016). The analysis procedure describes that low oil level or contamination causes poor lubrication, resulting in premature wear, reducing the useful life of some models of agricultural tractors (LORENCOWICZ; UZIAK, 2015; AL-SUHAIBANI; WAHBY, 2017). From the factors identified, it is also important to mention the regulation of brake pedals (ÖHMAN *et al.*, 2004, AL-SUHAIBANI; WAHBY, 2017). Brake components and similar

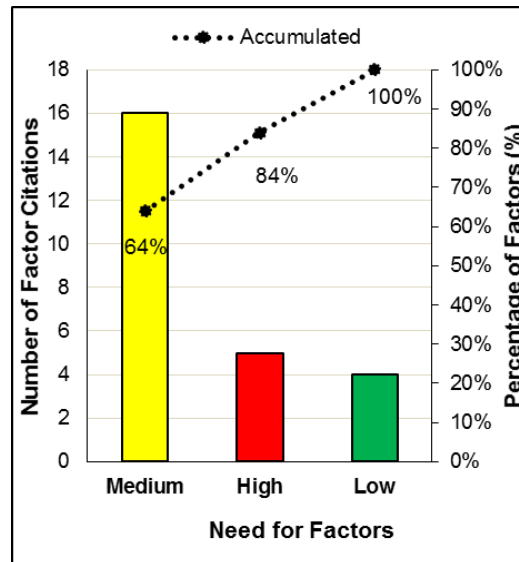
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products accounted for 2,2% of Brazilian exports of agricultural tractor auto parts in 2015 (ABIPEÇAS, 2016).

The efficient control of the maintenance of agricultural tractors is a precondition for the success of any planning. In addition to allowing longer tractor life and reducing the potential for failures during agricultural operations, it reduces production costs (ROHANI; ABBASPOUR-FARD; ABDOLAHPOUR, 2011, LIPS; BUROSE, 2012, LORENCOWICZ; UZIAK, 2015). For Morris (1988), estimates of tractor maintenance and repair costs are important for tractor replacement decisions and for the farm's overall budget. This control can be done by means of field notebooks, daily reports or from a specific computer program (ÖHMAN *et al.*, 2004; SOPEGNO *et al.*, 2016). Thus, Table 2 sought to systematize a set of factors that must be considered in maintaining agricultural tractors to keep them in good condition, enough to provide high availability and operationally. Considering not only typical maintenance tasks such as cleaning, lubrication, protection, adjustments and diagnoses (KUSZ; MARCINIAK, 1995) but strategies that are differential, based on the observations of the tractor user and technical interpretations.

Figure 3 shows the participation of the high, medium and low needs in the 25 factors found in the RBS for analysis of the maintenance of agricultural tractors. The average need factor represents 64% (16) of the total (25). Subsequently, the high need factor is 20% (5) and the low necessity factor is 16% (4). Through the design of the maintenance factors, it is possible to contemplate a new bias to carry out an adequate maintenance in agricultural tractors, which according to the existing literature, presents an indicative of high need for some particularities and low for others, however, all necessary to keep the equipment in the best usability conditions. From the analysis of Figure 3 it is also observed that there is a lack of studies regarding the development and improvement of the factors that effectively exert a greater weight in the process of maintenance of agricultural tractors, confirming the results found in the research of the article that there is a lack of information regarding the factors of high and low need.

**Figure 3 - Maintenance Factor Requirements.**



Source: Authors (2018).

In addition, through the results obtained, due to the high technology embedded in an agricultural tractor, its operators need to be professionals trained constantly in the technical part and also motivated, able to participate in a bigger philosophy of the company in the search of high levels of efficiency (RALPH *et al.*, 2012; BOCHTIS *et al.*, 2014). In this way, to perform the agricultural operation in an efficient and safe way, to register the work data (operation performed, location, time and area worked, fuel consumption), are fundamental measures to develop a good agricultural maintenance planning. However, in order to carry out all the procedures analyzed, it is necessary that the traditional process of maintenance of agricultural tractors be constantly revised and adapted according to technological progress.

## 5. CONCLUSION

The objective of the article was to identify and present a proposal of analysis factors for the maintenance of agricultural tractors, as well as their technical characteristics and modes of operation. As analyzed in the research, some maintenance conditions must be adapted to provide an increase in its service life and to avoid operating problems. The main maintenance factor identified in the literature refers to the verification of the level and the exchange of oil of the front axle, characterized as the procedure of analysis of greater necessity and that reduces the durability of some models of agricultural tractors.

In addition, the article contributed with farm tractor operators who seek to better understand maintenance definitions and concepts, and to provide researchers and stakeholders with a study on the subject. The results provide a larger and more complex list of factors related to farm tractor maintenance. Such characteristics could further support further studies of the area, researchers may benefit from a deeper and more rigorous understanding of the elements that explain the maintenance of the agricultural tractor.

The description of the results was focused and critical, structured, as far as possible, to increase the knowledge about the maintenance of agricultural tractors, given their relevance and relevance in the agricultural machinery sector, necessary for the execution of the productive processes. in agriculture, and therefore must present the best possible functionality. The main limitation of the research is related to the focus of RBS. A broader proposal of factors for the maintenance of agricultural tractors could be developed if they were considered as international bases for theses, dissertations and books. Another restriction is related to the criteria adopted in data searches in periodicals. As the theme is specific, other search criteria could be used to increase the number of articles identified in the search.

As a recommendation for future studies, it is suggested to conduct research that deepens the field of knowledge of agricultural tractor maintenance, such as: i) implement the maintenance factors identified in the study in different agricultural properties characterized as land ownership and small property; ii) to verify the suitability of maintenance in autonomous agricultural machinery; iii) perform an additional factor analysis to verify if the elements are what really explains the maintenance of the agricultural tractor; and iv) an additional study related to the maintenance of tractors with farm performance.

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