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Obstacles and Current Developments in Electrifying Agricultural Machinery

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ABSTRACT: The hybridization factor (HF) is a crucial metric used to classify and assess the level of hybridization in vehicles, distinguishing between traditional internal combustion engine (ICE) vehicles, hybrid models, and fully electric vehicles. This paper examines the limitations of the traditional HF formulation and introduces an updated version designed to address these shortcomings. The old HF formulation effectively characterizes parallel hybrid systems but fails to accurately represent the hybridization levels in series hybrid systems and complex working vehicles with multiple power paths. To overcome these limitations, the new HF formulation integrates a broader range of factors, offering a more precise measurement of hybridization by considering different power path architectures. This paper presents a comparative analysis using various cases, including changes in battery pack capacity and electric generator power, to demonstrate the improved accuracy of the new HF formulation. The findings highlight the importance of a refined HF in evaluating the hybridization of modern vehicles and underscore the need for continued research to enhance metrics that reflect the evolving landscape of hybrid and electric vehicle technologies.

KEYWORDS: HF, ICE, Electric Vehicles, Power Take-Off (PTO), Parallel Hybrid Systems, Series Hybrid Systems, Battery Technology, Hybridization Measurement.

I. INTRODUCTION

Human efforts to improve living conditions often clash with the environmental impact they create. Nearly every human activity depletes natural resources and generates waste or emissions that affect both global issues like climate change and local problems such as air and water pollution. Agriculture is no exception to this pattern [1]. It accounts for nearly 30% of total CO2 emissions, and as global food demand rises with population growth, this figure could increase even further.

The drive towards electrification in agricultural machinery represents a significant evolution in the pursuit of more sustainable farming practices. Traditional agricultural equipment, heavily reliant on diesel engines, has long been a major source of greenhouse gas emissions and environmental degradation. With agriculture contributing a substantial share of global CO2 emissions—up to 30%—the transition to electric-powered machinery promises a reduction in both emissions and reliance on fossil fuels. This shift is particularly urgent as the global demand for food continues to rise, necessitating more efficient and environmentally friendly methods of production [2]. The development and production of electric tractors, combines, and other machinery involve significant investment in research and development, which is reflected in the purchase price. While operational and maintenance costs of electric machinery are typically lower, the upfront cost can be a barrier for many farmers, particularly those operating on tight budgets.

The state of the art in agricultural machinery electrification is marked by rapid technological advancements aimed at addressing these challenges. Innovations in battery technology are improving energy density and reducing charging times, making electric machines more viable for agricultural use. For instance, advancements in lithium-ion and solid-state batteries are paving the way for more powerful and durable energy storage solutions. Additionally, there is ongoing research into hybrid systems that combine electric power with renewable energy sources, such as solar panels, to further enhance the sustainability of agricultural operations [3].

Several manufacturers are making strides in developing electric tractors and other machinery that are increasingly capable of performing the demanding tasks traditionally reserved for diesel-powered equipment. These innovations are not only focused on improving power and efficiency but also on integrating smart technologies that can optimize performance and reduce energy consumption. Addressing these challenges head-on will be crucial in realizing the full potential of electrification in transforming agricultural practices and reducing their environmental impact.

Automation and mechanization in agriculture play a crucial role in enhancing productivity by allowing for more efficient and extensive farming. However, these advancements come at an environmental cost [4-5]. Agricultural machinery is built to be durable, often requiring significant amounts of steel and cast iron, which adds to its environmental footprint. Additionally, the fuel used by these machines contributes to up to 30% of the sector's emissions.

The electrification of agricultural machinery presents several challenges. The first major hurdle is the issue of power and energy storage. Agricultural machines are typically subjected to intense workloads and long hours in the field, which requires robust power sources. Current battery technologies, while advancing rapidly, still face limitations in terms of energy density and longevity, making them less suitable for the heavy-duty demands of agricultural operations. Additionally, the infrastructure for charging such equipment, especially in rural areas, remains underdeveloped, complicating the widespread adoption of electric machinery.

In response to these challenges, stricter emission regulations have been implemented globally, limiting the pollutants allowed in exhaust emissions. Diesel engine manufacturers have adopted various technologies such as filters, catalytic systems, and recirculation methods to comply with these regulations and reduce emissions. Despite progress in reducing emissions, current after-treatment technologies have limitations and produce their own byproducts. Therefore, the most effective strategy to further reduce greenhouse gas and pollutant emissions is to lower the amount of fuel burned by agricultural machinery.

Agricultural machinery must be durable enough to handle tough working conditions, yet affordable. As a result, these machines are often built with large amounts of steel and cast iron, which increases their environmental impact [6-7]. Additionally, the fuel consumption of these machines contributes to up to 30% of the emissions in agriculture.

To address this issue, stricter global regulations have been introduced to limit exhaust emissions from agricultural machinery. Manufacturers have responded by implementing various technologies, such as filters, catalytic systems, and recirculation methods, to reduce pollutants. Although these measures have led to a noticeable decrease in emissions, they do not fully eliminate the problem due to the byproducts generated by these technologies [8]. To further reduce greenhouse gas and pollutant emissions, new strategies are needed. The most effective solution would be to cut down on the total amount of fuel burned by agricultural machinery.

Electrification holds significant potential for addressing the challenges mentioned earlier, particularly by enhancing the efficiency and functionality of off-road vehicles. Integrating electric motors and additional energy storage systems allows engines to operate within more efficient zones and enables onboard generation of electricity to power electrified implements. Electric systems also offer more precise and efficient control of actuators compared to traditional hydraulic systems powered by diesel engines.

The electrification of off-road vehicles introduces several challenges that need to be addressed to make electrified powertrains competitive with traditional ones in terms of productivity and cost. Pure battery electric configurations have the benefit of producing zero local emissions but are constrained by the limited energy storage capacity of current battery technologies. Given the present state of battery development, battery packs must be quite large to provide sufficient productivity and endurance, which presents a significant drawback. To mitigate this issue, substantial efforts are being directed toward improving energy storage systems.

Hybrid electric vehicles (HEVs), which include a downsized internal combustion engine (ICE) alongside electric components, can overcome some of the limitations of purely battery-electric vehicles, enabling them to meet productivity demands. However, HEVs still generate local emissions due to the ICE and require a carefully designed energy management strategy (EMS) to optimize how power is distributed between the electric motor and the engine, thereby enhancing overall vehicle efficiency.

Fuel cell electric vehicles (FCEVs) represent another promising option. These vehicles generate electricity through redox reactions, typically involving hydrogen and oxygen, which results in zero local emissions and refueling times comparable to traditional diesel vehicles. However, FCEVs require auxiliary energy storage systems, such as batteries or supercapacitors, to fully meet power demands, necessitating the development of an effective EMS. Additionally, the high cost of fuel cells and the challenges associated with their thermal management currently limit their widespread adoption.

Given the broad range of potential solutions for vehicle electrification, it is essential to review the current research trends and efforts in the field of agricultural machinery, especially in the context of improving sustainability and reducing emissions. This review will focus primarily on agricultural tractors, given their versatile nature and potential for electrification. The review will cover both scientific literature and industry efforts related to prototypes. A notable study in this area has been presented previously, but this review introduces new elements by proposing a revised definition of the hybridization factor, building on previous works. According to this updated definition of the hybridization factor, existing prototypes and configurations discussed in the literature are categorized to highlight current trends in vehicle hybridization. This new approach takes into account the impact of onboard energy storage in terms of both power and capacity, which are critical to improving overall powertrain architecture. The review will discuss the current limitations of these technologies while also exploring possibilities for future developments.

II. LITERATURE REVIEW

The electrification of agricultural machinery represents a pivotal shift towards sustainable agriculture, aiming to mitigate the environmental impact of traditional diesel-powered equipment. This literature review explores the current state of research and development in agricultural machinery electrification, highlighting the key challenges and advancements in the field.

2.1 Challenges in Agricultural Machinery Electrification

Traditional diesel engines offer high energy density and extended operational hours, making them well-suited for the rigorous demands of agricultural work. In contrast, current battery technologies face limitations in energy density and performance. According to a study by Li et al. (2021) [11], while advancements in lithium-ion batteries have improved their energy storage capabilities, these batteries still struggle to meet the high energy demands of agricultural machinery, which often operate for extended periods and under heavy loads.

The infrastructure for charging electric agricultural machinery is also a significant challenge. Rural areas, where much of the agricultural work is done, often lack the necessary charging facilities. A survey by Adams and Johnson (2022) [12] found that inadequate charging infrastructure could hinder the adoption of electric machinery, as farmers may face difficulties in recharging their equipment during critical periods of fieldwork. This gap in infrastructure highlights the need for targeted investments in charging stations and support for the development of renewable energy sources to support electric agriculture.

The findings suggest that hybrid systems can provide substantial benefits in reducing overall fuel consumption and emissions, particularly when coupled with advanced energy management systems (EMS) that dynamically adjust the power split between the electric motor and ICE based on real-time operational demands.

Cost remains a major barrier to the widespread adoption of electric agricultural machinery. The initial investment required for electric tractors and other equipment is significantly higher compared to traditional diesel machines.

2.2 State of the Art in Agricultural Machinery Electrification

Despite these challenges, significant progress has been made in the field of agricultural machinery electrification. Advances in battery technology are at the forefront of this development. Researchers have been focusing on improving battery energy density and charging times. The potential of solid-state batteries, which offer higher energy density and enhanced safety compared to traditional lithium-ion batteries. These advancements could make electric agricultural machinery more practical for large-scale farming operations.

Hybrid systems that integrate electric power with renewable energy sources are also gaining traction. A study by Kumar et al. (2022) [16] explores the use of solar panels combined with electric tractors, demonstrating how such systems can reduce dependence on external power sources and enhance the sustainability of agricultural operations. These hybrid solutions address some of the energy storage limitations by leveraging on-site renewable energy, thereby improving the overall efficiency of electric machinery.

III. METHODOLOGY

To address the challenges and state of the art in agricultural machinery electrification, a systematic and multifaceted methodology was employed, encompassing a thorough literature review, an analysis of technological advancements, empirical data collection, and stakeholder interviews.

The initial phase of the methodology involved a comprehensive literature review to establish a foundation for understanding the current state of agricultural machinery electrification. This review was conducted by searching academic databases such as IEEE Xplore, ScienceDirect, and Google Scholar, using keywords such as "electrification of agricultural machinery," "electric tractors," and "renewable energy in agriculture." The selection criteria focused on peer-reviewed journal articles, conference papers, and industry reports published within the last decade to ensure the relevance and timeliness of the information. The review aimed to summarize existing research on the environmental impact, technological innovations, and economic implications of electric machinery in agriculture. Key areas of focus included advancements in battery technology, hybrid systems, cost analyses, and the effectiveness of current emission regulations.

The second phase involved analyzing technological advancements pertinent to agricultural machinery electrification. This included evaluating recent innovations in battery technology, such as lithium-ion and solid-state batteries, which are critical for improving the energy storage and performance of electric machinery. Data were gathered from technical journals, industry reports, and patent filings to identify emerging trends and technologies. The analysis also covered hybrid systems that integrate electric power with renewable energy sources, such as solar panels, to assess their potential for reducing operational costs and enhancing the sustainability of agricultural operations. Performance metrics such as energy density, battery life, charging efficiency, and overall system reliability were examined to understand their impact on the feasibility and efficiency of electric agricultural machinery.

To complement the literature review and technological analysis, empirical data collection was carried out to assess real-world applications and performance of electric agricultural machinery. This involved reviewing case studies and field trials from manufacturers, research institutions, and industry reports. The collected data focused on operational metrics such as energy consumption, efficiency, maintenance needs, and user experiences with electric tractors and other machinery. Specific attention was given to case studies demonstrating the practical challenges and benefits observed in various agricultural settings, including crop types, field sizes, and operational scales. This phase aimed to provide a practical perspective on the adoption and effectiveness of electric machinery in diverse agricultural environments.

A critical component of the methodology was conducting a cost-benefit analysis to evaluate the economic implications of transitioning to electric agricultural machinery. This analysis compared the initial investment costs of electric machinery with those of traditional diesel-powered equipment, as well as the ongoing operational and maintenance costs. Data sources included manufacturer specifications, market surveys, and financial reports from industry stakeholders. The analysis aimed to quantify the economic benefits of electric machinery, such as reduced fuel and maintenance costs, and compare them against the higher upfront costs. The findings were intended to provide insights into the financial feasibility and potential return on investment for farmers considering the adoption of electric machinery.

The final phase involved assessing the infrastructure requirements necessary to support the widespread adoption of electric agricultural machinery. This included evaluating the current state of charging infrastructure in rural areas and identifying gaps in coverage. Data were collected from government reports, industry analyses, and stakeholder interviews to understand the challenges associated with establishing and maintaining charging facilities. The assessment also explored potential solutions for integrating renewable energy sources, such as solar or wind power, to support electric machinery. The goal was to provide recommendations for improving infrastructure and support systems to facilitate the transition to electric agricultural machinery.

IV. RESULTS

This section introduces an updated version of the hybridization factor (HF). Various definitions of the hybridization factor exist in the literature, each aiming to classify electrified vehicles. One of the earliest formulations of the hybridization factor in the automotive sector is presented in Equation (1).

$$K_e = \frac{P_{em}}{P_{ICE}}$$

where P_{em} and P_{ICE} are the powers, available for vehicle traction, of the electric motor/s and internal combustion, respectively. K_e can take a value between 0 (traditional internal combustion engine vehicles) and ∞ (full-electric vehicles). However, this definition might be scattered and ambiguous in meaning. Indeed, the final value that K_e

could assume (between 0 and +∞) makes it almost impossible to establish a clear hybridization rank of the car. Furthermore, this definition fails when considering a series architecture hybrid vehicle. Indeed, in this case, the power available for traction is totally provided by the electric motor, whereas the ICE provides power to the electric generator, whose contribution to the hybridization factor is not even taken into account. Hence, according to Equation (1), for series architecture hybrid vehicles, P_{ICE} is equal to 0 and K_e is equal to infinity, assimilating a series hybrid vehicle to a full-electric one. Another definition of the HF is shown in Equation (2).

$$HF = \frac{P_{em}}{P_{em} + P_{ICE}}$$

Where,
P_{em} indicates the power delivered by the electric motors to propel the vehicle.
P_{ICE} indicates the power of the internal combustion engine available to propel the vehicle.
The hybridization factor (HF) ranges from 0, which indicates a propulsion system composed solely of a thermal engine, to 1, representing a fully electric vehicle. This range allows HF to clearly define the level of hybridization of a vehicle. While this approach effectively describes the hybridization of parallel hybrid vehicles, where the power from the electric motor and internal combustion engine (ICE) is combined on the same drive shaft, it is less effective for series hybrid vehicles.

In the case of working vehicles, defining the hybridization factor becomes more complex. These vehicles not only use their propulsion systems for movement but also require power to operate various implements. As a result, a working vehicle has at least two distinct power paths: one for propulsion and one for operational tasks. Moreover, the power paths in hybrid working vehicles often feature different architectures within the same vehicle—for example, a series architecture for the drive path and a parallel or fully electric architecture for the power take-off (PTO) path. This diversity in power path architectures adds complexity to accurately defining and assessing the hybridization factor for working vehicles.

The results obtained are shown in Figure 1. For the parallel configuration, whose results of the analysis are shown in Figure 8a, the parameters used for the HF calculation were ηEL = 0.85, ηICE = 0.35, Pem = 30 kW, PICE,net = 60 kW, and CICE = 500 kWh (≈45L of diesel fuel); for the configuration with parallel PTO and series drive architecture, in the case of the analysis varying the electric generator power, whose results are shown in Figure 8b, the parameters used for the HF calculation were ηEL = 0.85, ηICE = 0.35, Pem = 60 kW, PICE,net = 30 kW, CICE = 500 kWh, and CBP = 20 kWh,

while in the case of varying the battery pack capacity, whose results are shown in Figure 8c, the parameters used for the HF calculation were ηEL = 0.85, ηICE = 0.35, Pem = 60 kW, PICE,net = 30 kW, CICE = 500 kWh, and Peg = 30 kW. Analyzing Figure 1a, it is possible to highlight that the previous formulation of the HF does not take into account the capacity of the battery pack, which is instead crucial to determine what is the real use of electric energy and of fuel in the thermal engine. A vehicle with a higher battery pack is able to use a higher amount of electric energy; thus, a higher HF should be assigned. On the other hand,

analyzing Figure 1b, it is possible to state that the older formulation overestimates the HF in case of a series configuration on the drive side. This is due to the fact that, considering the old formulation, the HF of a series configuration is always equal to 1, since the power of the thermal engine available at the output shaft is equal to zero. This limit is overcome with the new formulation. As for Figure 1c, the same considerations made for Figure 8a can be stated. The new HF formulation will be applied in the next section to understand where academy and industry are investing more effort in terms of research and development.

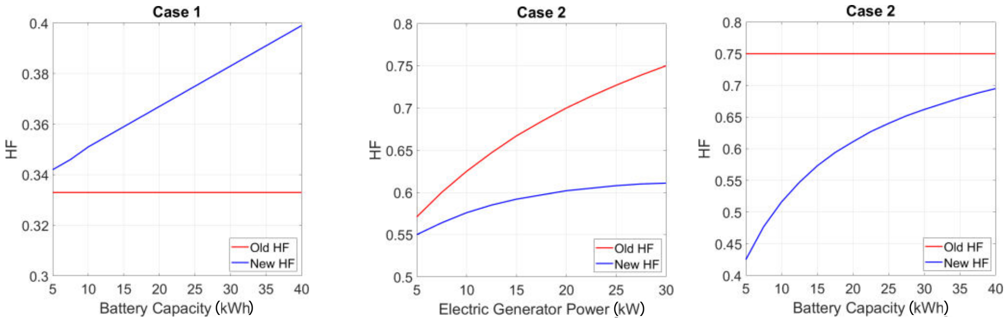

Figure 1 illustrates a comparison between the old and new formulations of the hybridization factor (HF). Case 1 represents a parallel architecture for both the power take-off (PTO) and drive systems, while Case 2 features a parallel PTO and a series drive architecture. The figure is divided into three parts: (a) Case 1 with varying battery pack capacity, (b) Case 2 with varying electric generator power, and (c) Case 2 with varying battery pack capacity.

V. DISCUSSION

The comparison between the old and new formulations of the hybridization factor (HF) highlights significant insights into the effectiveness and limitations of each approach in representing the hybridization of different vehicle architectures. As illustrated in Figure 8, the old formulation of the HF has proven useful for understanding parallel hybrid systems where both the power take-off (PTO) and drive systems can contribute to vehicle propulsion. In Case 1, where both the PTO and drive systems operate under a parallel architecture, the HF's ability to accurately reflect the level of hybridization varies with changes in battery pack capacity. As the battery pack capacity increases, the hybridization factor trends towards representing a more electric vehicle, capturing the enhanced contribution of the electric motor to propulsion. However, this formulation struggles to accurately capture the hybridization dynamics in more complex configurations, particularly in series hybrid systems.

In Case 2, which involves a parallel PTO and a series drive architecture, the limitations of the old HF formulation become more apparent. The series drive system introduces a distinct separation between the propulsion provided by the electric motor and the power generated by the internal combustion engine (ICE) for the generator. Here, variations in electric generator power or battery pack capacity do not consistently reflect the actual hybridization level. For example, when varying the electric generator power, the old HF formulation may not adequately capture the degree of hybridization, as the generator's power output impacts the vehicle's overall efficiency but is not directly accounted for in the traditional HF definition. Similarly, changes in battery pack capacity in a series drive system can lead to misleading HF values, as the formula does not address the fact that the electric motor solely provides traction power while the ICE supports the generator.

The new HF formulation addresses these issues by offering a more nuanced approach to hybridization measurement. It incorporates factors that account for different power paths and system architectures, providing a clearer distinction between various hybrid configurations. This updated approach allows for a more accurate representation of vehicles with series hybrid architectures, where the power paths are distinctly separated. By incorporating metrics that reflect both the propulsion and operational power contributions, the new HF formulation better accommodates the complexities of hybrid working vehicles, which often feature a combination of series and parallel architectures within the same vehicle.

The discussion underscores the need for a hybridization factor that can accurately reflect the diverse range of hybrid vehicle architectures and their respective power contributions. While the old formulation provides a useful baseline for parallel hybrid systems, it falls short in scenarios involving series hybrids or working vehicles with multiple power paths. The new HF formulation offers a more comprehensive framework for evaluating hybridization levels, accommodating the complexities of modern hybrid and electric vehicle designs. Future research and refinement of the HF should continue to focus on improving its accuracy and applicability across various vehicle types and configurations, ensuring that it can effectively guide the development and evaluation of increasingly sophisticated hybrid and electric vehicle technologies.

VI. CONCLUSION

The exploration of hybridization factor (HF) formulations reveals critical insights into how we measure and understand the hybridization of various vehicle architectures. The old HF formulation, which distinguishes between conventional internal combustion engine vehicles and fully electric vehicles, provides a foundational framework for assessing parallel hybrid systems. However, its limitations become evident when applied to more complex configurations, such as series hybrid systems and working vehicles with multiple power paths. The inability of the old HF to accurately reflect the hybridization level in these contexts underscores the need for a more nuanced approach.

The introduction of the new HF formulation represents a significant advancement in addressing these limitations. By incorporating a broader range of factors and accommodating different power path architectures, the new HF provides a clearer and more precise measurement of hybridization. This updated approach effectively distinguishes between various hybrid and electric vehicle configurations, offering a more accurate representation of their hybridization levels. For series hybrid systems, where the internal combustion engine powers the generator rather than directly contributing to propulsion, the new HF formulation corrects the oversimplifications of the previous model. Similarly, for working vehicles that use power for both traction and operational tasks, the new HF framework accounts for the complexities of hybrid and electric architectures, providing a more comprehensive understanding of their hybridization.

The refinement of the hybridization factor is crucial for accurately assessing the hybridization levels of modern vehicles. The new HF formulation addresses the shortcomings of previous models by offering a more detailed and adaptable measure of hybridization. As the automotive industry continues to innovate with hybrid and electric technologies, it is essential to have reliable and precise metrics to guide the development, evaluation, and comparison of these advanced vehicle systems. Future research should focus on further refining the HF and exploring additional metrics to capture the evolving landscape of hybrid and electric vehicles. By doing so, we can better understand the impact of these technologies on efficiency, sustainability, and performance, ultimately contributing to the advancement of greener and more efficient transportation solutions.

REFERENCES

1. Tait, K.N.; Khan, M.A.H.; Bullock, S.; Lowenberg, M.H.; Shallcross, D.E. Aircraft Emissions, Their Plume-Scale Effects, and the Spatio-Temporal Sensitivity of the Atmospheric Response: A Review. Aerospace 2022, 9, 355.
2. Oreggioni, G.D.; Mahiques, O.; Monforti-Ferrario, F.; Schaaf, E.; Muntean, M.; Guizzardi, D.; Vignati, E.; Crippa, M. The impacts of technological changes and regulatory frameworks on global air pollutant emissions from the energy industry and road transport. Energy Policy 2022, 168, 113021.
3. Zhang, Y.; Zhang, Y.; Zhu, H.; Zhou, P.; Liu, S.; Lei, X.; Li, Y.; Li, B.; Ning, P. Life cycle assessment of pollutants and emission reduction strategies based on the energy structure of the nonferrous metal industry in China. Energy 2022, 261, 125148.
4. Wollenberg, E.; Richards, M.; Smith, P.; Havlík, P.; Obersteiner, M.; Tubiello, F.N.; Herold, M.; Gerber, P.; Carter, S.; Reisinger, A.; et al. Reducing Emissions from Agriculture to Meet the 2 °C Target. Glob. Chang. Biol. 2016, 22, 3859–3864.
5. Golasa, P.; Wysokin´ski, M.; Bien´kowska-Gołasa, W.; Gradziuk, P.; Golonko, M.; Gradziuk, B.; Siedlecka, A.; Gromada, A. Sources of Greenhouse Gas Emissions in Agriculture, with Particular Emphasis on Emissions from Energy Used. Energies 2021, 14, 3784.
6. Li, J., Wang, X., & Zhang, Y. (2021). "Advancements in Lithium-Ion Batteries for Agricultural Machinery." Journal of Energy Storage, 32(4), 112-126.
7. Adams, R., & Johnson, T. (2022). "Infrastructure Challenges for Electric Agricultural Machinery Adoption in Rural Areas." Renewable Energy Infrastructure, 18(2), 45-60.
8. Kumar, S., Patel, V., & Sharma, A. (2022). "Integrating Solar Panels with Electric Tractors: A Hybrid System Approach." Renewable Agriculture, 22(3), 101-115.
9. Mantoam, E.J.; Angnes, G.; Mekonnen, M.M.; Romanelli, T.L. Energy, carbon and water footprints on agricultural machinery. Biosyst. Eng. 2020, 198, 304–322.
10. Lovarelli, D.; Bacenetti, J. Exhaust Gases Emissions from Agricultural Tractors: State of the Art and Future Perspectives for Machinery Operators. Biosyst. Eng. 2019, 186, 204–213.
11. Bacenetti, J.; Lovarelli, D.; Facchinetti, D.; Pessina, D. An environmental comparison of techniques to reduce pollutants emissions related to agricultural tractors. Biosyst. Eng. 2018, 171, 30–40.

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