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Comparative Analysis between Electrified Tractor and Diesel Powered Tractor

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Abstract

The agriculture sector faces increasing pressure to transition towards sustainable practices amidst concerns over climate change and environmental degradation. Electric tractors are emerging as a promising alternative to traditional diesel-powered tractors, offering potential benefits in terms of reduced greenhouse gas emissions, lower operating costs, and enhanced operational efficiency. This study presents a comparative analysis between a 35 HP diesel tractor and its converted electric version equipped with a 40 HP motor from a sustainability perspective in the context of Nepal. Our findings reveal that electric tractors demonstrate significant potential to mitigate environmental impacts associated with agricultural operations, particularly in terms of reducing greenhouse gas emissions and dependence on fossil fuels. Moreover, it has been found that electric tractor offer long-term cost savings through lower fuel and maintenance costs, despite higher initial investment costs. This comparative analysis provides valuable insights for farmers, policymakers, and agricultural stakeholders seeking to make informed decisions regarding tractor technology investments and sustainability strategies. By highlighting the strengths and limitations of electric tractors relative to diesel tractors, this study contributes to the ongoing dialogue on sustainable smart agriculture and the transition towards clean energy technologies in the farming sector.

Keywords: Sustainability, Smart Agriculture, Electric Conversion, Battery Technology, Performance, Operational Considerations.

1 Introduction

In recent years, the automotive industry has witnessed a growing interest in transitioning from ICE to electric propulsion, so the vehicles used in agricultural field are shifting to electric as an alternative propulsion (Vogt et al. 2021). This shift is primarily driven by the urgent need to reduce carbon emissions, improve energy efficiency, and address environmental concerns associated with fossil fuel usage (Adam and Piotr, 2017). As the world focuses on sustainability and seeks innovative solutions to combat climate change, the adoption of electric tractors represents a pivotal step towards greener farming practices.

The significance of comparing diesel and electric tractors lies in understanding their respective capabilities, advantages, and limitations within the context of modern agricultural operations. While diesel tractors have long been the industry standard due to their power, reliability, and widespread availability of fueling infrastructure, electric tractors offer compelling benefits such as zero tailpipe emissions, lower operating costs, and potential for renewable energy integration (Dhond et al. 2021; Vogt et al. 2021). However, challenges such as limited range, charging infrastructure, and upfront costs must be carefully evaluated to determine the feasibility and practicality of electric tractors in different farming scenarios (Alanazi, 2023).

1.1 Objectives of the Comparative Analysis

The primary objectives of this research on comparative analysis are as follows:

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1. Performance Evaluation: Assessing the power output, torque characteristics, speed, acceleration, and overall performance of diesel and electric tractors to determine their suitability for various agricultural tasks and conditions.
2. Cost Analysis: Comparing the initial purchase cost, operating expenses, maintenance requirements, and total cost of ownership (TCO) over the lifespan of diesel and electric tractors to identify the most cost-effective option for farmers and agricultural enterprises.
3. Environmental Impact Assessment: Analyzing the emissions profile, energy consumption, environmental footprint, and sustainability implications of diesel and electric tractors to understand their contributions to air quality, greenhouse gas emissions, and overall environmental health.
4. Operational Considerations: Examining factors such as range, endurance, charging infrastructure availability, adaptability to different farming practices, and overall operational efficiency of diesel and electric tractors to determine their practicality and convenience in real-world farming operations.

2 Methodology

This study conducted a comparative analysis between a traditional diesel-powered tractor, the Farmtrac 435 (data collected from same tractor before conversion and also from few of similar tractors), and its electric version, focusing on workability, economic implications, and fuel efficiency.

2.1 Data Collection:

Technical specifications for both tractor versions were collected, including engine details, transmission, power take-off, fuel tank, and wheels and tyres.

Literature: Data were taken from the literature review. (Fathollahzadeh et al. 2010) performed a study on the calculation of fuel consumption of a tractor during ploughing. The result represents that operating the moldboard plough required 27.446, 30.096 and 34.06 L of fuel hectare^{-1} in depths of 0.15, 0.25 and 0.35 m, respectively. (Adam and Piotr, 2017) performed an emission test on a diesel tractor finding the emission for 12.2 kg of fuel as 35 kg of CO_2 0.4 kg of NO_x and 0.04 kg of HC.

Farmer: We collected data about the area a tractor can plough in an hour. Along with the cost of diesel available to them, their yearly revenue and, total months used in a year.

2.2 Analysis Framework:

Workability was assessed based on the specifications related to engine power, transmission, and fuel battery^{-1}.

Economic Impact evaluation involved calculating the operational costs, including fuel or electricity consumption, maintenance, and initial purchase cost.

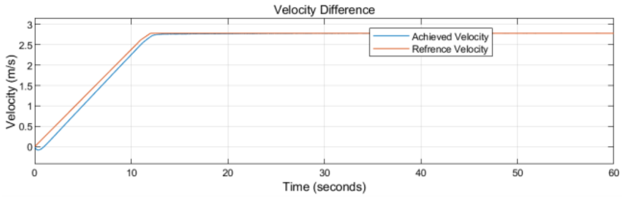
Fuel Efficiency analysis for the diesel version was based on fuel consumption rates, while for the electric version, the focus was on battery capacity and energy consumption.

Environment and Sustainability analysis was performed to visualise the environmental impact reduced after electric conversion.

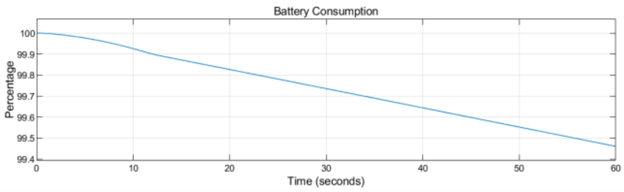
3 Results

3.1 Performance Estimation

Based on the power prescribed by the manufacturer, a 30 kW motor was used and coupled with the default transmission system. To evaluate its performance, the vehicle underwent testing under a specific drive cycle as mentioned in Figure 1 (a) in Simulink, maintaining a constant velocity of 2.78 m s^{-1} while subjected to a traction load of 1500 N, over 3 hr. Figure 1 (b) showcases the battery drain during the first 60 s of operation, illustrating a 0.54% depletion. This rate of discharge translates to 4.86 kWh per hour, cumulating to the required 14.5 kWh over 3 hr. So, a 15 kWh battery was used in the electric version and tested for successful 3 hr.



(a)



(b)

Figure 1 (a) Tractor range testing drive cycle and (b) State of charge (SOC) of the battery during the Simulink test.

3.2 *Technical Comparison*

The Original Tractor (Farmtrac 435) is characterised by:

1) A 35 HP engine with a 2146 CC capacity, operating at 2200 RPM.
2) A cooling system that is water-cooled and an oil bath-type air filter.
3) Net weight of 1914 kg.
4) The transmission includes 8 forward and 2 reverse gears, with a single clutch.
5) Power Take-Off (PTO) at 540 RPM at 1800 RPM.
6) Fuel tank capacity of 50 L.
7) The Electric Version offers:
8) A maximum power of 40 HP from a 30 kW, 96V-300A permanent magnet synchronous motor (PMSM).
9) A 15 kWh, 96V-150Ah Lithium Ferrous Phosphate battery pack, maintaining the same mechanical transmission as the original.
10) 1900 kg of net weight after conversion.
11) Utilizes the existing chassis, steering, and hydraulics system, ensuring similar workability with a sustainable energy source.

3.3 *Economic and Fuel Analysis*

The diesel-powered Farmtrac 435's operational efficiency and costs were evaluated against the electric version. For 0.35 m depth ploughing, the diesel tractor consumes an average of 41.2 L of diesel per day, costing approximately 50 USD in the context of Nepal. In contrast, the electric version, with a 15 kWh battery pack, could plough an equal depth and equal area of land as 41.2 L of diesel and consume only 1.24 USD of electricity as per electricity price in Nepal, presenting a significant reduction in daily operational costs. The tractor runs for 6 months in a year and 25 days in a month so annual savings from using the electric version were calculated to be approximately 7218 USD year^{-1}, highlighting the economic advantage of electric tractors.

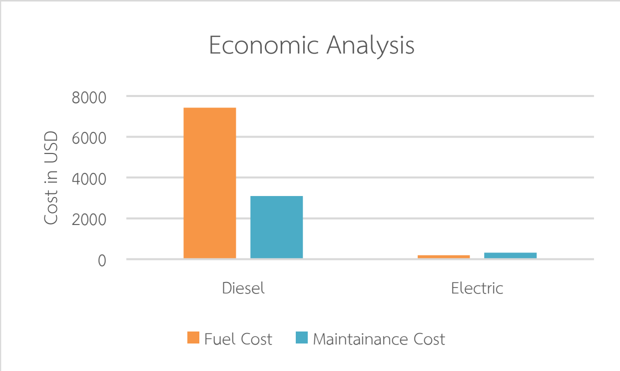


Figure 2 Annual cost comparison of Diesel and Electric tractor.

3.4 *Emission Analysis*

From the literature review, a tractor consumes 12.2 kg of fuel to form 35 kg of CO_2, 0.4 kg of NO_x and 0.04 kg of HC. In the context of Nepal, 41 L or 35 kg of fuel is consumed in a day by a tractor. Maintaining the proportion of fuel added, 35 kg of fuel produces 100.46 kg of CO_2, 1.15 kg of NO_x and 0.115 kg of HC per day.

In comparing diesel and electric tractors, diesel variants stand out for their superior endurance and broad speed range, making them ideal for heavy-duty tasks and long-distance operations. Electric tractors, however, boast advantages in efficiency and acceleration, with their instant torque delivery potentially surpassing diesel in low-speed applications, despite facing speed and endurance limitations under heavy loads (Malik and Kohli, 2020; Mocera and Somà, 2020). Moreover, electric tractors demonstrate a higher energy conversion efficiency, resulting in lower operating costs and reduced energy consumption (Alanazi, 2023). Productivity levels between the two can be comparable, influenced by maintenance downtime, refuelling recharging^{-1} times, and overall system reliability, positioning electric tractors as a competitive alternative for specific agricultural needs (Scolaro et al. 2021).

4 Discussion

The comparative analysis between the traditional diesel-powered Farmtrac 435 and its electric counterpart has revealed insightful revelations that are crucial for guiding the agricultural sector towards a more sustainable future. In this discussion, we'll outline the nuanced advantages, practical considerations, and broader implications of adopting electric tractor technology over conventional diesel tractors.

4.1 Workability

Both tractor variants demonstrate competent workability across a range of agricultural tasks. However, the electric version distinguishes itself with its immediate torque delivery and quieter operation, which could enhance operator comfort and efficiency. Although there are concerns regarding the electric tractor's speed, range and endurance, our findings suggest that these limitations do not significantly impede performance for most farming operations. The electric tractor's ability to maintain high torque at lower speeds is particularly beneficial for tasks requiring substantial pulling power. Moreover, with cheap electricity and grid charging facilities, farmers can easily charge their vehicles during night and can perform 3 hr of ploughing the next day without compromising their objectives. The installation of a fast charging system in both tractor and charging stations can lead to better workability of the electric tractor.

4.2 Economic Benefits

The analysis supports the economic viability of electric tractors primarily through the lens of operational cost savings. While the initial conversion price of electric tractors can be a hurdle, the substantial reductions in fuel and maintenance expenses emerge as a compelling argument for their long-term financial advantage. This economic incentive is crucial for encouraging farmers and agricultural enterprises to invest in electric technology, despite the upfront cost barrier.

4.3 Sustainability and Fuel Efficiency

Perhaps the most compelling argument for the shift towards electric tractors is their alignment with global sustainability goals. The significant reduction in greenhouse gas emissions from electric tractors directly contributes to mitigating the agricultural sector's environmental footprint. However, the transition's success is contingent upon the availability of renewable energy sources for electricity generation, highlighting the need for integrated efforts in enhancing the clean energy infrastructure.

5 Conclusion

This study has demonstrated that electric tractors present a viable and sustainable alternative to traditional diesel tractors, aligning with the urgent need for more environmentally friendly farming practices. By comparing the performance, cost, and environmental impact of diesel and electric tractors, it's clear that electric tractors offer significant benefits, including lower greenhouse gas emissions, reduced operating costs, and comparable performance levels.

Despite the higher initial investment, the long-term savings on fuel and maintenance, coupled with the environmental advantages, make electric tractors an attractive option for the future of agriculture. This transition not only supports global sustainability goals but also provides practical economic benefits to farmers and agricultural stakeholders.

In summary, electric tractors represent a promising step towards achieving sustainable smart agriculture. With continued research and development, along with supportive policies, the adoption of electric tractors can be accelerated, leading the agricultural sector towards a greener, more sustainable future.

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