Revolutionizing Agriculture: Electric Tractors for Indonesian Sustainable Farming

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ABSTRACT

The global shift towards electrification has extended its reach to non-road mobile machinery, with a primary focus on agricultural applications. This growing trend reflects the larger shift towards sustainability and the minimization of environmental effects. Electric tractors and other farm machinery have gained popularity due to their environmental benefits, cost savings, and technological advancements. The electric non-road vehicles are not only quieter and more environmentally friendly but also offer the potential for reduced operational costs, making them a compelling choice for farmers looking to modernise their equipment while adhering to stringent environmental regulations. Thus, the concept of an electric tractor becomes an important topic to be discussed. This paper will discuss the development of tractors in Indonesia and proposed design for electric tractors that are suitable for Indonesia to support sustainable farming.

Keywords: *electrification, non-road mobile machinery, sustainable, environmental impact, efficiency.*

ABSTRAK

Pergeseran global menuju elektrifikasi telah memperluas jangkauannya ke mesin bergerak non-jalan raya, dengan penekanan yang signifikan pada aplikasi pertanian. Tren pertumbuhan ini mencerminkan gerakan yang lebih luas menuju keberlanjutan dan pengurangan dampak terhadap lingkungan. Traktor listrik dan mesin pertanian lainnya semakin populer karena emisinya yang lebih rendah dan peningkatan efisiensi. Kendaraan listrik non-jalan raya ini tidak hanya ramah lingkungan tetapi juga menawarkan potensi pengurangan biaya operasional, menjadikannya pilihan menarik bagi petani yang ingin memodernisasi peralatan mereka sambil mematuhi peraturan lingkungan yang ketat. Oleh karena itu, konsep traktor listrik menjadi topik penting untuk dibahas. Tulisan ini akan membahas perkembangan traktor di Indonesia dan usulan desain traktor listrik yang cocok digunakan di Indonesia untuk mendukung pertanian berkelanjutan.

Kata kunci: elektrifikasi, mesin bergerak non-jalan raya, berkelanjutan, dampak lingkungan, efisiensi.

I. Introduction

Numerous tractors in operation today continue to rely on diesel oil as their primary fuel source (Bessette, D. L.,2022). While diesel engines have traditionally been the workhorses of agriculture, their environmental impact is a growing concern. Diesel combustion generates harmful emissions, including Particulate Matter (PM) and Greenhouse Gases (GHG), contributing significantly to air pollution and climate change (Teoh, Y. H, 2022; Mejia, 2022; Ardebili, 2020). Currently, Indonesia is in the top rank in terms of CO_2 emissions when compared with countries in Southeast Asia as shown in Figure 1. As is known, most agricultural machines or called Non Road Vehicles in Indonesia use fossil fuels such as gasoline as the main energy source.

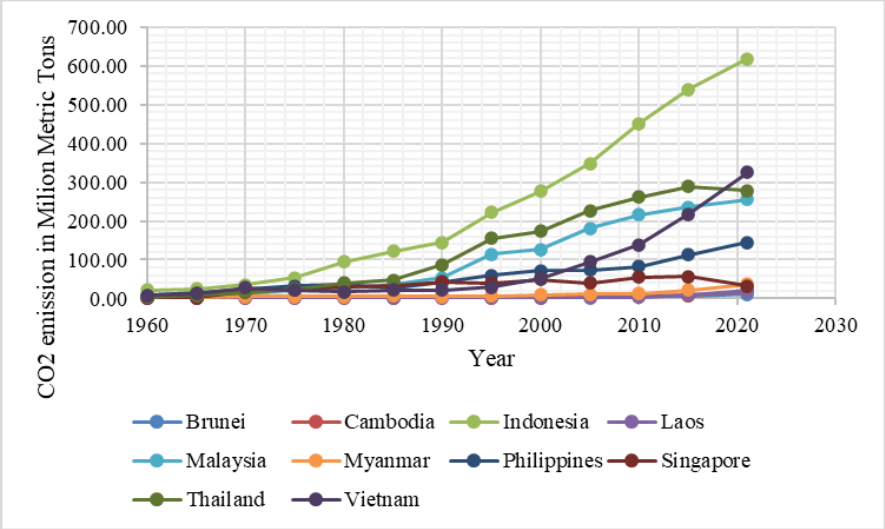

Figure 1. CO_2 emissions in Southeast Asia by country (Andrew and Peters, 2022)

As the global places a greater emphasis on sustainability and environmental responsibility, the agricultural sector is increasingly recognizing the need to transition away from diesel-powered tractors and embrace cleaner alternatives , such as electric tractors (Mocera, F, 2023) or those powered by alternative fuels (Assandri, 2022), in order to mitigate their harmful effects on the environment.

Stricter regulations governing Internal Combustion Engine (ICE) installations in non-road mobile machinery have been a driving force behind the shift to electrification (Tapia et al, 2023; Kiiski, T, 2023). Governments and regulatory bodies worldwide have recognized the urgent need to improve the efficiency while lowering the emissions of these vehicles. These regulations set emission standards and performance targets for ICE-based machinery, compelling manufacturers to explore cleaner alternatives (Tapia et al, 2023). As a result, the development of electric tractors and equipment has gained momentum as they provide a viable solution to meet these demanding regulations while delivering the necessary power and performance for various agricultural tasks.

The electrification of non-road mobile machinery in agriculture signifies a pivotal moment in the industry. Farmers are presented with the opportunity to adopt innovative, eco-friendly technologies that not only align with regulatory requirements but also offer long-term economic benefits. The transition to electric agricultural machinery isn't merely an environmentally conscious choice; it's a step towards a more sustainable and efficient future in farming.

As one of a region known for its abundant and varied biological ecosystems, Indonesia engages in global agricultural product exports, making substantial contributions to their economies. Rice serves as a fundamental food staple in Indonesia. As one of the world's major rice producers, Indonesia is the third-largest rice producer globally (R.L Naylor, 2002; Bandumula, 2018) and has various rice varieties suited to its different regions.

Nowadays, there is a growing emphasis on sustainable agriculture practices in Southeast Asia especially Indonesia to address environmental concerns and ensure long-term food security. Initiatives such as farming technology have gained traction. The adoption of modern agricultural technologies, including electric tractors aiming to increase productivity and reduce environmental impacts (Gonzalez-de-Soto, M, 2016; Mousazadeh, H, et al., 2011). In Indonesia, farmers have been grappling with the urgent need to boost productivity in the face of a looming food crisis, making food security a pressing national and global priority. As illustrated in Figure 2, Indonesia's standing in the global food security index is a cause for concern, as it currently ranks 63th worldwide, significantly behind neighbouring nations such as Singapore, Malaysia and Vietnam.

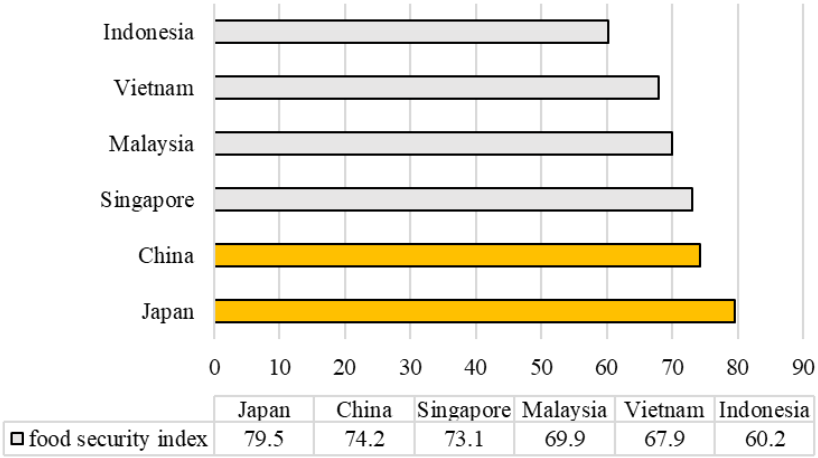

Figure 2. Global food security index (Economist Impact, 2022)

For this reason, sustainable agriculture by optimising agricultural procedures, maximising use of equipment and innovation in existing technology is the key to surviving in the agricultural industry and increasing added value in the agricultural value chain. The innovative technology development proposed through this paper is the Electric Tractor for Agriculture (ETA) which uses an electric motor as the main driver and a battery system as the main power source. It is hoped that this innovation can contribute to solving energy, environmental and food problems.

II. Indonesia Current States for Agricultural Tractor

Indonesia has embraced sustainable agriculture by employing several nationwide approaches, including the National Agenda 21, National Development Initiatives, and the Revitalization Plan for Agriculture, Fisheries, and Forestry. These strategies have been put into action by entities such as the Central Planning Agency (BAPPENAS), the Ministry of Agriculture, and the Ministry of Environment. To address environmental concerns and promote sustainable agriculture, Indonesia needs to develop green technologies, such as electric tractors.

Sustainable agriculture can contribute to climate change mitigation by reducing greenhouse gas emissions and sequestering carbon in soils. Practices like agroforestry and organic farming can help minimise the agricultural sector's carbon footprint. Sustainable farming practices can improve the long-term economic viability of smallholder farmers by reducing input costs and increasing yields. This can lead to improved livelihoods for many rural communities.

There is limited information on the history of the development of paddy plough technology in Indonesia. However, research suggests that wet rice cultivation has been practised in Indonesia for centuries[9]. The use of ploughs in rice cultivation has been documented in various societies, including Indonesia[12]. The Indonesian government has set greenhouse gas (GHG) reduction targets in the agriculture sector, aiming to reduce emissions by 0.3 percent and 0.4 percent compared to the 2016 baseline in an unconditional mitigation scenario and a conditional scenario, respectively. Sustainable agriculture practices are being implemented in Indonesia to increase overall agricultural productivity while minimising environmental damage. Some of the sustainable agriculture practices implemented in Indonesia include sustainable agroforestry methods, crop rotation, greater crop diversity, use of cover crops, and no-till and reduced-till techniques. The Indonesian Agency for Agricultural Research and Development is leading the shift towards sustainable agriculture practices in the country[1][5].

III. Electric Tractor and Sustainable Agriculture

1. Benefits of electric tractors in sustainable farming

Electric tractors are a modern innovation in the agriculture sector that hold significant promise in addressing some of the challenges faced by Indonesian farmers, particularly those related to sustainability and economic viability. These tractors are designed to replace traditional

diesel-powered tractors with electric or hybrid alternatives. Electric tractors, also known as e-tractors or electric farm machinery, are agricultural vehicles powered by electricity instead of traditional internal combustion engines. They can be fully electric, relying solely on batteries, or hybrid, combining both electric and diesel power. These tractors are gaining popularity globally due to their numerous advantages: environmental benefits, cost savings, reduced noise and energy efficiency.

2. Electric tractors in supporting specific sustainable farming practices in Indonesia

Agriculture 4.0 technologies synergize to significantly reduce emissions and enhance sustainability in the agricultural sector. Agriculture 4.0, which encompasses digitalization, IoT (Internet of Things), and data analytics, will optimise resource management (Javaid, 2022). Furthermore, electric tractors development also can play a crucial role in supporting Indonesia specific sustainable farming. By significantly reducing emissions and enhancing air quality, these tractors address environmental concerns in densely populated agricultural regions. In a country with considerable renewable energy potential, these tractors can integrate seamlessly with clean energy sources, contributing to Indonesia's shift towards sustainable agriculture.

Indeed, electric tractors offer more than just emission reduction benefits. Their quieter operation can significantly reduce noise pollution, which is a valuable advantage for farmworkers and neighbouring communities alike. Traditional diesel-powered tractors can generate substantial noise levels over the permitted limits, 90 dB (Duvnjak, 2018). It can lead to potential health issues for the operator and disturbances in rural areas where farming is prevalent. Electric tractors, on the other hand, operate with much less noise, creating a more peaceful and sustainable farming environment. This reduction in noise pollution not only enhances the well-being and safety of farmworkers but also contributes to a better quality of life for people living near agricultural areas, fostering harmonious coexistence between agriculture and rural communities. As catalysts for economic resilience and environmental stewardship, electric tractors not only support Indonesia's sustainable agriculture goals but also serve as examples, fostering community engagement and awareness for a more eco-conscious farming landscape.

IV. Design of Electric Tractor for Agriculture (ETA)

Designing an electric tractor for agriculture involves multiple considerations, including the mechanical designs, power train, performance, cost, and environmental impact. In terms of mechanical design, the hand tractor is quite popular in Indonesia because of the more affordable cost. Furthermore, several parts of the agricultural land terrain elevation is not suitable for four wheeled tractors. Another consideration is the water proof design for preventing the water disturbing the electrical system. The water can come from top, below, or side of the tractors.

In terms of power train, the selection of power should be carefully chosen. According to the usual product utilised by the local farmers, there are several classes. The classification can be low powered, usually for cultivator, and high powered /tractor with power below 6 HP and more than 8 HP, respectively. For the small powered motor, a prototype has been developed by Wikarta et al. (2023). This prototype is suitable for cultivating agricultural land. On the other hand, the high powered tractor is usually for the four wheeled tractor.

Apart from being environmentally friendly, which is the central aspect of this research, the ETA is easy to operate by implementing an electric starter and push-button speed shifter, as shown in Table 1. It makes the ETA easier to operate than conventional tractors, which must still be cranked to operate. Apart from ease of operation, ETA also has less noise polution compared to conventional tractors. Based on this illustration, it shows that ETA certainly has a more environmentally friendly impact.

Table 1. Comparison of ETA Features and Functionality with Conventional Tractors

No	Features	Differences	
		Conventional	**ETA**
1	*Starting Effort*	Needs to be cranked	Electric Starter

2	Average Noise Level	noise	less noise
3	*Shifter Speed*	Manual	Push button
4	Pollution	Yes	No
5	*Efficiency Cost*	IDR 34.000,-/8 hour	IDR 13.494,-/8 hour

An example design of electric tractors has the specification as described in Table 2. The power storage is a Lithium iron phosphate battery. This battery is selected because of the more compact and weight-efficient compared to conventional lead-acid batteries, and capable of enduring numerous discharge cycles.

Table 2. Specifications of ETA

No	Parameter	Value
1	Power storage	Battery LiFePO4
2	Power output	10 HP
3	Shifter Speed	Push Button
4	Starting	Electric Starter

Based on the results of the ETA illustration above, it can be seen in Table 3 that ETA is superior in cost efficiency. For one day operation with an estimated 8 hours of work, ETA looks superior with much cheaper cost results than Conventional Tractors. In 8 hours of operation, the electric tractor only requires 9.34 kWh of power with an estimated rate per kWh of IDR. 1,444.70,- hence in 8 hours of work, ETA only costs IDR. 13,494,-. When compared with a conventional tractor, which costs Rp. 34,000,- for one day of operation, ETA promises more affordable prices and is more environmentally friendly.

Table 3. Calculation of Efficiency Costs for Conventional Diesel Tractors and ETA

	Conventional Tractor	***Electric Tractor for Agriculture* (ETA)**
Energy usage	5 litres of diesel	9.34 kWh
Working time	8 hour	8 hour
Cost	34,000,-	13,494,

V. Conclusion

As a country consisting of many islands with significant variations in geographic conditions, tractor designs must be able to deal with a variety of terrain, including flat rice fields, hills and agricultural land that may be swampy or rocky. Designing a tractor that is compact, but strong enough and has good manoeuvrability will be critical to success in a variety of farming conditions. Apart from that, from an economic perspective, based on calculations, electric tractors are much more economical than conventional diesel tractors. Taking into account topographic challenges and the economic side, the design of a two-wheeled electric tractor is very suitable for agriculture in Indonesia.

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