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Renewable energy and Mechanisation in the smallholder sector: Experiences from Wedza e-mobility pilot study

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Transport is often overlooked as a challenge to agriculture and agricultural value chains in development projects, despite the fact that one of the identified factors that could potentially accelerate mechanization in the smallholder sector is the provision of efficient and affordable transport. Women farmers bear the burden of manual work and reduced rural mobility disproportionately, as they spend a higher proportion of their time on both productive and reproductive work, thus compromising on the expected outputs when engaging in agricultural activities related to CSA. To evaluate the use of a 3 wheeler that runs on renewable energy by smallholder farmers, a pilot project was initiated in Wedza district of Zimbabwe, targeting 90 women in groups of 3. A mixed method research approach was used to collect both qualitative and quantitative data through surveys and case studies. Besides providing reliable and affordable first and last mile solutions, the 3 wheeler contributed to adaptation to climate change by providing alternate sources of non-farm based livelihoods options. 52% of women farmers used the 3 wheeler for agricultural mechanization; 23% for buying and selling various goods; 16% provided taxi transport services; and 9% did not specify its use. The initiative improved agricultural productivity by reducing drudgery, and it also contributed to the reduction of greenhouse gas emissions.

Keywords: Mechanisation, women farmers, renewable energy, rural mobility, E- mobility.

INTRODUCTION

Agricultural mechanization has been defined primarily in terms of power and transportation (Chisango and Ajuruchukwu, 2010). On the other hand, the Food and Agriculture Organization of the United Nations (FAO) defines mechanization as the application of tools, implements, and machinery in order to achieve agricultural production (Diao et al., 2016). Agricultural mechanization and the transport sector world over are greatly dependent on conventional sources of energy to meet their energy requirements. These sources of energy contribute to air quality concerns as well as high greenhouse gas emissions. Although a number of studies have been conducted on the impacts of mechanization on productivity, not much attention has been paid to

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mobility. As a result, rural areas in developing countries continue to face mobility challenges which pose a great hindrance to social and economic development (ARE, 2022). Access to fossil fuels as a source of energy is not only costly, but the use of such sources of fuel also impacts negatively on the environment. This paper focuses on renewable energy as an alternate source of energy in agricultural livelihoods in response to climate change. Renewable energy for e-mobility is equally important to agricultural mechanization in rural areas, as the provision of transport is a necessity across all value chains. Agricultural mechanization has been defined primarily in terms of power and transportation (Chisango and Ajuruchukwu, 2010). On the other hand, the Food and Agriculture Organization of the United Nations (FAO) defines mechanization as the application of tools, implements, and machinery in order to achieve agricultural production (Diao et al., 2016). Agricultural mechanization and the transport sector world over are greatly dependent on conventional sources of energy to meet their energy requirements. These sources of energy contribute to air quality concerns as well as high greenhouse gas emissions. Although a number of studies have been conducted on the impacts of mechanization on productivity, not much attention has been paid to mobility. As a result, rural areas in developing countries continue to face mobility challenges which pose a great hindrance to social and economic development (ARE, 2022). Access to fossil fuels as a source of energy is not only costly, but the use of such sources of fuel also impacts negatively on the environment. This paper focuses on renewable energy as an alternate source of energy in agricultural livelihoods in response to climate change. Renewable energy for e-mobility is equally important to agricultural mechanization in rural areas, as the provision of transport is a necessity across all value chains.

LITERATURE REVIEW

Zimbabwe's agricultural sector is predominantly smallholder-led, with over 2 million communal farmers relying on rain-fed agriculture, and close to 70% of them making a livelihood on less than two hectares of land. The majority of these small scale farmers are vulnerable to climate change and economic shocks. In addition, many farmers are still using traditional and outdated agricultural technologies, resulting in low productivity of crops and livestock. This low productivity is further exacerbated by climate change, fuel shortages, fluctuating fuel pricing policies in the macroeconomic environment, low skills and knowledge base of farming, weak research, farmer training and extension systems as sources of technology and innovation, shortage of inputs and equipment, low levels of mechanization, reliance on rain-fed agriculture, limited access to market information and marketing facilities, limited access to finance, limited security of tenure, pest and disease attacks including the Fall Army Worm in cereal crops, Tuta Absoluta in tomatoes, and Theileriosis (tick-borne diseases) in cattle, low capacity to manage post-harvest losses, mismatch between production and domestic consumption, and increased incidence and intensity of climate shocks (Agric Survey, 2019). Coupled with these challenges, the constraints of cross-cutting issues, such as transportation in relation to markets and services, and gender issues, cannot be downplayed. It has been observed that interventions that focus on reforming public transport can have a positive impact on women's participation in developmental issues, including agriculture (Zimbabwe National Gender Profile, 2017). Long distances to health facilities, schools, and markets are also a major concern. In response to these challenges, a range of assistance schemes have been adopted by governments and NGOs. However, CSA technologies on offer have displayed low appreciation for mechanization and transport to meet the demands of smallholder farmers. In addition, research and development into mechanization as a vital input has also been frequently neglected (Thebe, 2018).

Why mechanize in CSA

Agricultural mechanization is the application of mechanical technology and increased power to agriculture, largely as a means to enhance the productivity of human labor often to achieve results well beyond what is achievable with human labor alone. Rural mechanization is characterized by the use of fossil fuel engines for multiple purposes, such as providing power for shallow wells, pumping from water bodies, two-wheel and three-wheel tractors, road and track transport vehicles, harvesters, threshers, grain mills, timber mills, and processing equipment (Biggs and Justice, 2015). The diverse need for transport and tillage calls for alternate means of energy in order to mitigate climate change. Although two-wheel and three-wheel fossil fuel tractors have been introduced in the country, Mobility for Africa focuses on solar battery-charged three-wheelers for multipurpose interventions in rural development. Mechanization of all sorts and at various degrees eases and reduces hard labor (drudgery), relieves labor shortages, improves farm labor productivity, increases productivity and timeliness of agricultural operations, improves the efficient use of resources, enhances market access, and contributes to mitigating climate-related hazards (Sims et al., 2016). Advantages of mechanization in CSA include saving labor, which can be employed for non-farm activities that increase household incomes. Mechanization ensures that farmers meet the growing demands of power and timeliness of operations as agricultural systems become more intensively managed. Previous studies (Alobo, 2016) have shown that mechanization has enabled farmers to intensify production and improve their livelihoods, though these gains are being increasingly challenged by climate change (CIMMYT, 2014). Mechanization can transform farm family economies by facilitating increased output and reducing the drudgery of hand-powered production. Despite the vital role of rural mechanization in raising rural incomes, the resources invested in the selection of appropriate mechanization options have been declining in the FAO. This is achieved through high-quality service provision on the farm, for road transport, and in the development of entrepreneurial enterprise in the agricultural product value addition chain (Kienzle et al., 2013). Mechanization influences adoption of CSA, as it offers multidimensional benefits to the farmer. Mechanizing agriculture can lessen the burden of shelling, harvesting, threshing, spraying, and irrigation; it also reduces energy demand, and contributes to the reservation of energy for increased meat and milk production. The use of renewable energy does not only contribute to increased productivity of a given crop but also contributes to the building of adaptive capacity and resilience to climate change, thus reducing greenhouse gas emissions. This 'triple win' approach - the incorporation of intensification, adaptation, and mitigation goals into a single rubric - defines CSA (Taylor, 2018).

Need for renewable energy

The Government of Zimbabwe, in its NDCs (2021), addresses the country's commitment to reduce greenhouse gas (GHG) emissions and climate change concerns. Renewable-based off-grid technologies, such as renewable energy (RE) (Kuranel and Mohapatra, 2022) powered water pumps, biogas-based heating and lighting farm systems, and equipment for watering animals, can be used to support productive activity at all stages of the agriculture food chain. Furthermore, the installation of RE equipment, such as solar panels, wind turbines, or biomass digesters, can support irrigation (water pumping) and post-harvest activities, such as agro-processing and food preservation (drying, milling, pressing, and cooling) for storage and transport. Although much research has focused on mechanizing the productive level in agriculture, not much has been done to focus on transport as a supporting system in agricultural activities and practices. Generally, rural areas are overlooked in the transport discourse and may be left out when considering e-mobility, with much attention being given to urban development (Clement, 2022).

Actions such as introducing electric vehicles (EVs) that reduce greenhouse gases and increase the adaptive capacity of smallholder farmers can provide efficient and reliable transport for rural communities. EVs are a proven reliable technology, and it is now apparent that Africa should test various versions of EVs to meet the terrain and requirements for effective results in CSA. Owning a vehicle which requires less maintenance and downtime is very important, considering that most rural farmers rely on public transport and ox-drawn implements for transportation and spend around 30% of their income on transport expenses (Mwenye, 2019). Clement (2022) observed that transport costs for most low-income families are large and follow rentals and groceries. In addition, feminization of agriculture provides an opportunity to promote sustainable, gender-sensitive mechanization and means of transport in rural Africa (Sims et al, 2016).

The context

To contribute to the debate on CSA, e-mobility and mechanization, the paper presents experiences from a pilot study conducted in Wedza district of Mashonaland East, Zimbabwe in 2018-2020, by Mobility for Africa. Mobility for Africa is a startup organization with a vision to improve mobility, especially for women, in rural areas (www.mobilityforafrica.com). Smallholder farmers in the study area face similar problems to other farmers as discussed earlier. The introduction of e-mobility, focusing on a 3-wheeler, brought disruptive changes to a seemingly normal rural life. The 3-wheeler was introduced as a result of a baseline study that indicated that 85% of rural women needed transport to execute various tasks in their livelihoods. The major livelihood options in this study area included on-farm and non-farm options. Non-farm options served as adaptation strategies to climate change, as the district is prone to erratic and unreliable rainfall patterns. One of the hindrances to technology use is the initial capital costs of climate smart technologies. To address this issue, the project adopted a fleet sharing model and leasing model, which allowed beneficiaries to access new technology without having to own the means of mechanization. This resource sharing model enabled them to reduce the initial capital costs. Large farms have the collateral to access machinery, but small farms typically opt for renting rather than buying. The Mobility for Africa model promoted e-mobility through rental models of the tricycle at 15 USD per month and battery swapping at 1 USD per swap. The battery itself contributes to 40% of the tricycle cost, making it too expensive for small scale farmers to purchase one. To facilitate battery charging and swapping, one solar charging station was established at a central point. The farmers did not own the technology, and as such were not liable for any technological failures during the testing period. To ensure commitment and accountability to the project resources, MFA provided maintenance and technical backstopping, as well as rental and battery swapping payments. The project was unique in that it introduced mobility solutions across value chains, addressing several Sustainable Development Goals (SDGs), including Zero Hunger (SDG 2), Good Health and Wellbeing (SDG 3), Gender Equality (SDG 5), and Climate Action (SDG 13). Unlike previous projects that focused solely on supply and production nodes, the MFA project opened up opportunities for women in e-mobility to solve first and last mile challenges in the agriculture, education, and health sectors. The project particularly targeted women because they contribute about 70% of the agricultural labor, and the bulk of them are subsistence farmers. Even when both husband and wife are both farmers, women still perform 50% of the agricultural tasks on all major crops grown (Rukuni et al., 2006). Historically women have been excluded from land ownership through a combination of traditional and colonial patriarchal systems. Women farmers face a number of challenges that affect their practical and strategic needs. The introduction of income generating projects supported by reliable means transport, aimed to improve the economic position of women.

Previous studies have shown that small scale farming rarely provides sufficient means of livelihoods, and agro-based income generation projects are seasonal and even more at risk due to climate change. As a result, non-governmental organizations have supported a diversity of activities and income generating projects including new crops and small stock production, roadside trading of fruits, ornamentals, artwork, firewood, uniform making, small bakeries, and soap making. However, none of these income generating projects had a component of income generation focusing on mobility and, in particular, electric vehicles. The Wedza e-mobility project has shown that farmers can still access technologies through a renting/leasing model, and no collateral is required. Ownership of resources conveys the right to manage the resource and is a major source of collateral credit (Rukuni et al., 2006), taking into consideration that collateral for borrowing is a major limitation in the adoption of CSA. The resource sharing concept is a big contribution to the climate smartness of the technology and is also a form of sustainable intensification (SI). It provides opportunities for scaling up into other agricultural practices such as processing, irrigation, and tillage whose initial capital costs are prohibitive. The project played a key role in building institutional capacity and information dissemination to support widespread sustainable intensification. It demonstrated the linkages between sustainable intensification and adaptation by providing alternate sources of income for small-holder farmers. Generally, it is worth noting that farmers are often reluctant to adopt practices for climate change adaptation that may not yield improved returns on investments in the short term (Campbell et al., 2014). However, any practice that improves farm incomes allows farming households to build up their assets which can be used in times of stress or can put households on a different development trajectory altogether as an essential element of adaptive capacity. As much as CSA can support SI, the reverse is also often required. Whilst Campbell et al. (2014) emphasize on SI and diversification (exploiting complementarities between crops, across crop-livestock systems, and in terms of risk management), the Wedza project demonstrated that diversification to non-farm enterprises is a crucial part of building adaptive capacity in small-holder systems.

Objective of the study

The objective of the study was to assess the nexus between CSA and mechanization with a focus on use of the solar powered 3 wheeler in providing mobility solutions for small holder farmers.

METHODOLOGY

The study adopted a mixed method research approach to explore the nexus of e-mobility and CSA. The study sought to gather evidence from project participants and build arguments for scaling up e-mobility in solving first and last mile challenges in rural Africa. As is usual with such an approach, the study sought rich and detailed data to build a clear picture of the research contexts, and involved communities throughout the research cycle. Data was collected at 3 main intervals- the baseline, during implementation and at the end of a year’s experience in e-mobility. Experiences of the technology as being climate smart were indirectly extrapolated from the findings of the study. This was an appropriate approach, especially because CSA in the context of e-mobility is a new concept and is still being defined (Campbell et al., 2014). For the qualitative approach, a case study design was adopted and data on perceptions and use was collected through focus group discussions (FGD) and observations. For the quantitative approach, a survey was carried out using a semi-structured questionnaire to collect data on the use of vehicles for various productive and reproductive activities in the smallholder farmer's livelihoods. Real-time data on tracking the movement of the vehicle was enabled through the use of trackers attached to the tricycle, as well as the use of log sheets by users. This tracking was essential for mobility mapping. The study specifically targeted 30 farmer groups with 3 women in each group, as per the project design. Women were specifically targeted as they are disproportionately affected by mobility and mechanization challenges (Potter, 2008). Figure 1 shows the model adopted by the MFA to introduce the project.

RESULTS

Evidence on use of hamba

The introduction of the tricycle was relevant along the various value chains, since the majority of participants (98%) depended on agriculture for a living. From the

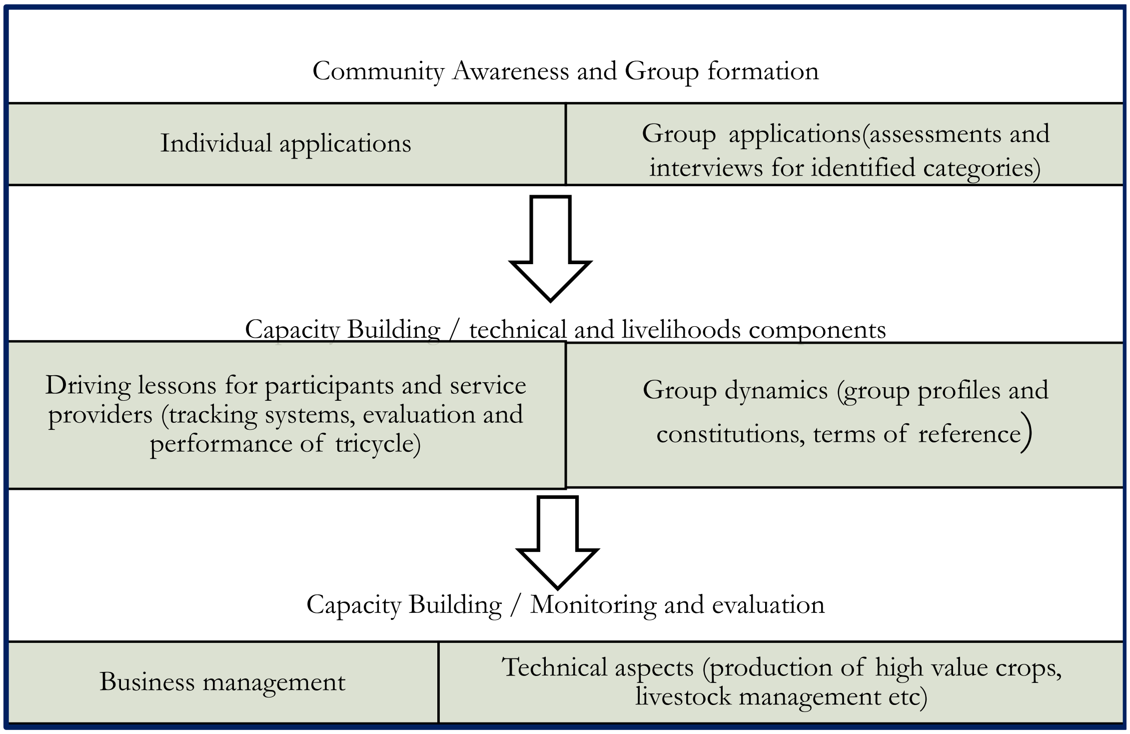

Figure 1. Model for introduction of e-mobility project- source Mobility for Africa.
Source: (Authors, 2021)

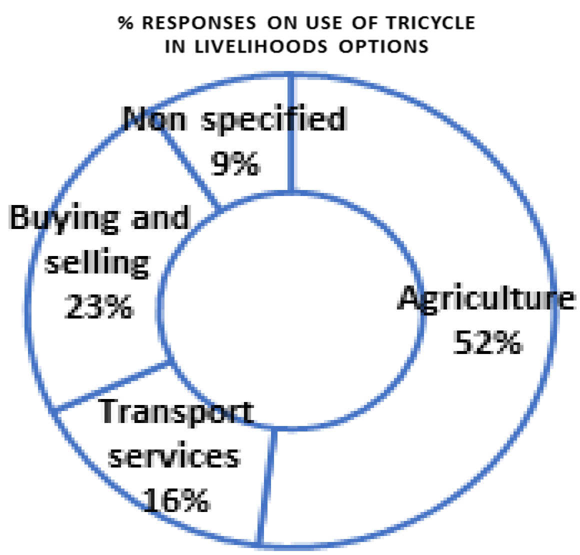

Figure 2. Livelihoods options and use of tricycle.
Source: (Authors, 2022)

study, 52% reported using the tricycle for agricultural purposes, 23 % and 16 % reported using it for non- farm activities such as buying and selling and transport services in the form of taxi services, respectively. These non- farm activities were less dependent on rain-fed agriculture. The participants relying on non –farm

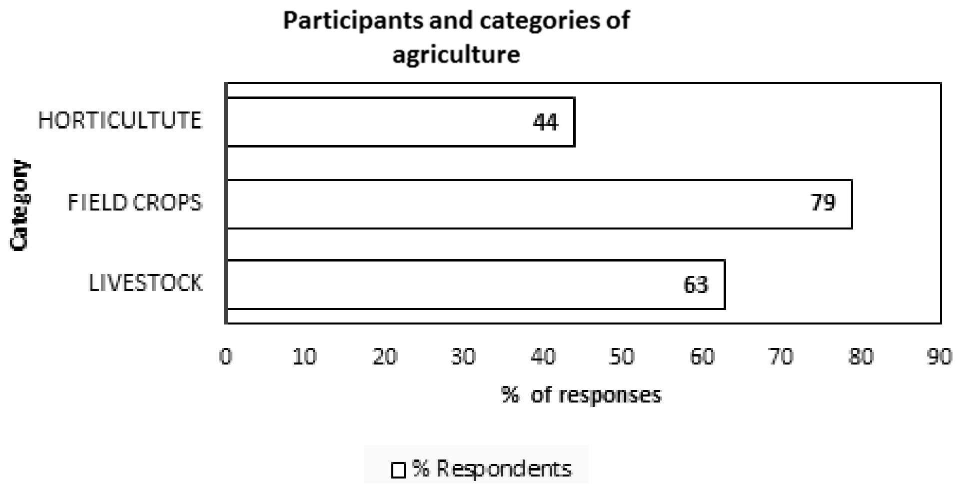

Figure 3. Use of tricycle in agricultural activities.
(Authors, 2022)

livelihoods options were relatively more resilient to erratic rainfall seasons as they had alternate sources of income. In line with Campbell et al. (2014) argument of Sustainable Intensification (SI), this group of farmers was most likely to adopt the technology as it generated income within a short-specified time (Figure 2). Figure 1 shows the model adopted by the MFA to introduce the project.

"We are into hoarding and selling of various items. In one week we spent 50% of our time hoarding and selling beer and tomatoes for sale within the community. 40% of the time is spent on transport services within the group to meet daily demands, and 10% of the time the hamba is idle. We gained a profit of 65USD in the first week of using the tricycle)"

Transport Taxi service- Vandudzo group had this to share:

"*We conducted 3 trips only during the first week as we had no confidence in riding the tricycle. We raised about 3.80 USD*." The study show that with every new technology participants need to build confidence and that patience and determination is needed. By 2022 taxi groups were generating around 300 USD per week.

Agriculture group

The results (Figure 3) indicate multiple use of the tricycle by women in various agricultural activities, with a majority of 79% using the tricycle for transporting organic fertilizers, mulch and other inputs to the field and produce from the field. The tricycle also served as a means of transport to cover distances to and fro the field, located some 6km from homesteads. The findings indicate even within the same sector, some operations require more mechanization depending on household enterprises. Agriculture-Chicken sales group had this to share:

"*We use the hamba to carry tobacco from tobacco barns, bags of piggery feeds from store room to pig sties; to sale our chickens in nearby farms; carry chicken feeds from markets. 67% of the time when we had access to tricycle, was allocated to productive activities, and 33% to reproductive work (fetching water, firewood, visiting the clinic and taking kids to school)*

Multiple benefits derived from e-mobility

The study findings (Table 1) relate well with similar findings from Jaleta et al. (2019), whereby two wheelers were promoted to reduce drudgery, but farmers ended up gaining multiple benefits. This study also recommends integration of diverse actors to introduce different components of mechanization. The solar powered tricycle solved multiple challenges faced by the farmers including reduced drudgery, saving costs and saving time. In addition, by using renewable energy, the project indirectly contributed to reduced carbon foot prints.

CONCLUSIONS AND RECOMMENDATIONS

The introduction of electric vehicles in rural areas of Zimbabwe and other parts of Africa is a new phenomenon. To promote the nexus between climate-smart agriculture (CSA) and mechanization, the project fell short of a number of factors, including a low uptake due to a hastened process coupled with limited funding.

Table 1. Benefits of using tricycle.

Variable	With tricycle	With ought tricycle
Number of maize buckets taken to millers	3	1
Cost-Travel to Masikana (15 km)	1 USD (Direct route)	6 USD (Pick and drop services)
Quantity of Avocados carried	3 buckets	1 bucket
Number of people using same transport to church	Whole family	1 individual
Fetching water- number of buckets carried	4 buckets	1 bucket
Fetching firewood –size of load	Big load	Small load by head or wheel borough

Source: (Authors, 2022).

To increase uptake of electric vehicles, there is a need to incentivize potential customers and to conduct consumer education and outreach programs to create awareness of the advantages of e-mobility in agriculture. Policies on e-mobility and mechanization should focus on customer hire services and should consider the high initial capital costs of batteries and solar stations. Furthermore, emphasis should be placed on creating demand and providing an enabling environment in the battery and energy sector. In terms of CSA, focus should be on providing affordable and clean energy along the various value chains. Therefore, the study recommends the adoption of policies that support the installation of charging infrastructure in public locations and strategic points in rural areas, in order to facilitate business. The Wedza experience has shown that the radius around each charging station should be kept to less than 10km to reduce energy loss due to dead mileage. Moreover, initial battery costs remain prohibitive, and therefore policies that promote increased investment in the domestic manufacture of EVs are needed.
From the Wedza experience the study also recommends the following:

1. Community shared asserts: Shared transport fleet can be diversified to shared mechanization for various agriculture implements. To solve challenges of high initial capital costs
2. Systematic introduction: New technology should be introduced step by step from solar powered transport to solar powered implements such as processing and irrigation equipment that do not depend on fossil fuels.
3. Multipurpose technologies (multipurpose): Mechanization should solve the many challenges faced by rural communities
4. The potential for e- mobility in reducing climate related challenges is high: For resilient livelihoods, agriculturalists need to think outside the box and propose policies that are inclusive to tackle as many SDGs as possible using appropriate and sustainable technologies.
5. Opportunities in e-mobility: Inclusion of multiple approaches/models to generate jobs and new income streams in the rural areas.
6. Diversification through e-mobility: Provides for resilience building in the face of a changing climate, thereby increasing the choices for alternate sources of livelihoods.

The need for further research on the carbon footprint resulting from the introduction of the solar-powered tricycle in Wedza cannot be overemphasized. This is due to the role the tricycle plays in complimenting mechanization in CSA, as well as its demonstrated climate-smartness in reducing drudgery and increasing production for smallholder farmers. Furthermore, its efficiency and reliability make it a viable option for both men and women to adopt.

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CONFLICT OF INTEREST

The author has not declared any conflict of interest.

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