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Household welfare improvement in the Mbulu district of Tanzania: does rural electrification matter?

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Access to electricity is crucial for basic human activities and serves as a direct measure of energy poverty. In recent years, intergovernmental organizations have made significant strides in rural electrification to ensure energy security for all (rural populations, the poor, and the vulnerable). In developing countries, there is a positive correlation between rural infrastructure enhancement and rural livelihoods. Since the early 2000s, in Tanzania, there has been a major government rural electrification initiative to boost rural development. However, the extent to which rural electrification improves rural livelihoods remains unclear. This study was conducted to investigate the impact of rural electrification on household livelihoods in Tanzania, using the Mbulu District as a case study. The study employed a mixed research approach, combining qualitative and quantitative methods. The data were collected from 447 respondents through surveys and interviews with households in electrified and non-electrified areas, where information such as income levels, health, education access, self-employment, and asset ownership was collected. The results indicated a significant 45% increase in household income following electrification compared to non-electrification. About 47% of the respondents earned over 1 000 000 Tsh per month post-electrification, compared to 6% before. Access to modern healthcare improved, with 36% of the respondents being able to afford medication after electrification compared to 13% before electrification. Furthermore, educational opportunities expanded where 31% of the children were enrolled in private schools after electrification compared to 11% before electrification. Asset ownership showed marked improvements, with fewer households living in mud houses (10% post-electrification, down from 22%); all this confirms the significant impact of rural electrification on the improvement of rural development and household livelihood. Our study concludes that rural electrification significantly boosts household income, health service provision, education, and overall welfare which have a significant impact on environmental management. It recommends continued investment and sustained efforts from stakeholders, including the Tanzania Electricity Supply Company (TANESCO) to address challenges hindering electricity service expansion in rural areas. This study provides a foundation for informed policy decisions and actionable strategies to promote sustainable development in rural communities.

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Environmental significance

This study demonstrates that rural electrification in Tanzania not only enhances household livelihoods but also contributes to environmental sustainability; through increasing household incomes and improving access to modern healthcare and education, electrification reduced reliance on environmentally damaging practices such as fossil fuel and biomass burning. Rural electrification improved asset ownership, led to better housing, and further reduced environmental degradation due to minimized deforestation. Thus, there is a need to integrate rural electrification into environmental management strategies to promote sustainable rural development and conservation efforts.

1. Introduction

Access to electricity is fundamental to ensure basic human activities and is a direct measure of energy poverty.[1] In recent years, significant steps towards rural electrification have been fostered by intergovernmental organizations with the scope to ensure energy security for all—especially rural people, the poor

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and the vulnerable.[1,2] Lighting and cooking are basic daily household activities and are strictly related to energy security.[3] Nevertheless, in most developing countries like Tanzania and the rural world, cooking and lighting are still done through polluting, ineffective and dangerous kerosene stoves, animal manure and primordial tools.[4–9] To enhance environmental, social and economic performances of rural households there is a need for stable and accessible energy access as it has a fundamental impact on daily household life improvement.[6,7,10,11] Studies show that besides behavioral and taste aspects affordability and level of education, rural electrification plays an important role in the context of the household-level energy transition improvement.[1,5,6,8,9,12–14]

Rural areas in developing nations have been negatively impacted by enduring challenges arising from limited access to sustainable energy,[15–20] which is essential for enhancing household welfare in terms of social, environmental, and economic development.[21] Globally, over 860 million people lack access to electricity as of 2018, which is a dropdown from the 1 billion in 2017.[22–25] Of these, 80% reside in rural areas, attributable to the high costs of grid extensions, the remoteness of villages and the scattered nature of village populations. In addition, some 2.7 billion people still rely on conventional energy sources for a variety of domestic tasks like heating, lighting, and cooking.[26] In rural Sub-Saharan African nations like Tanzania, restricted access to sustainable energy has blocked approximately 633 million people from having access to electricity, according to the IEA's energy report.[26] The Tanzanian government launched the initiative to promote rural electrification, provide sustainable access to electricity, and subsequently enhance household welfare in rural areas in response to this predicament.

Rural electrification is the process of supplying electrical power to remote locations and rural communities. This procedure attempts to automate income-generating operations like milking, food processing and storage, agricultural output, and machine operation, expanding the usage of energy beyond lighting and other domestic applications.[26] Similar to urban electrification, rural electrification refers to government measures in a particular nation to guarantee the distribution of power and energy in remote and rural areas. This government-led initiative intends to improve rural residents' life quality while facilitating the nation's transition from a lower to a higher economic status.[27] The government meets the larger share of costs for the infrastructure and service fees in rural areas since the majority of residents have limited incomes. This is because the emphasis is on providing services as opposed to profit-making. This is evident from the fact that rural energy is extensively subsidized in the majority of countries, to the point that service costs are far lower in comparison to urban areas.[28] This demonstrates that these projects which are primarily government-led initiatives are primarily aimed to improve rural household welfare.

Several initiatives are in place around the world to address the problem of rural electrification in general. By 2018 for instance, 100 million people in India's urban and rural areas had access to electricity, demonstrating the country's remarkable progress.[26] According to the 2018 country-by-country report from the International Energy Agency (IEA), Africa is also advancing, with an estimated 595 million people lacking access to electricity in 2018 compared to 610 million in 2013. This is because more people now have access to electricity, which has doubled from 9 million in 2000 to 20 million in 2018.[26] East African countries like Kenya, Tanzania, and Ethiopia have been commended for 50% of the increased access.[29] Despite the advancements, the distribution is still disparate, notably in Tanzania's rural areas. Increasing access to electricity in rural areas is considered a practical poverty alleviation strategy in emerging economies. Except for pastoralist communities that rely on animals such as donkeys and camels, human power is the sole source of energy supply in most rural parts of less developed countries. It is mainly used for food cultivation, processing, cooking, and fetching water and firewood. This results in extra time wasted in completing chores, as opposed to using electric power, which saves time. The two constraints of human energy and time have contributed to extreme poverty since households are unable to engage in additional income-generating activities.

The relationship between electricity and household welfare is not absolute, but it is based on the notion that power, as an essential basic requirement, can contribute to economic growth.[26] According to Akpan and Isihak,[30] access to electricity contributes significantly to socio-economic development in sectors such as health, education, agriculture, and household income. However, there is limited scientific evidence to support the use of electricity as a poverty-reduction strategy. Higher-income households benefit more from rural electrification in comparison to their low-income counterparts. According to Tanzania's National Census (2022), 70% of the population lives in rural areas and despite the government's numerous attempts to ensure electric connectivity in rural areas, these locations have been demonstrated to have enduring electricity problems.[30] In response, the government established the Rural Energy Agency (REA), which functions independently of the Ministry of Energy and Minerals of the United Republic of Tanzania (URT) to provide lasting solutions to these predicaments.[30] Since it is a non-union matter, the REA is tasked with ensuring, promoting, and facilitating access to modern energy services in the rural Tanzania mainland. The government's primary goal is to transform rural areas into modern locations by enhancing livelihoods; these transformations have however been constrained by limited access to electricity.[21] The Tanzanian Government's subsidy of rural electrification costs is intended to promote widespread access to electricity in rural areas. The Rural Energy Fund (REF), the Rural Energy Board (REB), and the Rural Energy Agency (REA) were founded to function in sync towards ensuring adequate provision of modern energy services in rural Tanzania. Once the infrastructure is in place, clients are required to pay only 27 000 Tanzanian shillings.[31] This is projected to transition the entire country into a modern economy, improve livelihoods, and promote urbanization. In 2019, 70% of the rural population had access to electricity, which is a remarkable upsurge from 49% in 2016. In line with this progress, 30% of households were

connected to the grid in 2019, in comparison to 20% in 2016.[31,32] Despite various government efforts to improve rural electrification in Tanzania, a large proportion of households remain impoverished, with the majority unable to meet optimal living costs. It is upon such a background that the current study analyzed the effect of rural electrification on household welfare in the Manyara Region, specifically the Mbulu District of Tanzania.

The Tanzanian Government has made remarkable efforts towards rural electrification, which is projected to ensure equitable improved livelihoods for all.[31] Tanzania, like many other nations, established the Rural Energy Fund (REF), the Rural Energy Board (REB), and the Rural Energy Agency (REA) to provide an adequate supply of modern energy services in rural areas. As a result of these initiatives, 69.8% of the rural population currently has access to electricity, which is an uptrend from the 49.3% in 2016 to 6.9% in 2019. Despite efforts and progress, only 24.5% of households were connected to grid electricity in 2020 and 16.9% in 2021.[32] To ensure long-term energy access, one technique of providing electricity to rural areas is through rural electrification. According to several reports, sustained access to electricity in rural areas has implications for rural household welfare. Social services (such as education and health), household income, and job creation are all noteworthy indices of household welfare improvement as detailed hereunder: Findings from empirical research demonstrate the relationship between household welfare and energy across nations. For instance, Olanrele[33] in Nigeria found that grid electrification greatly improves household income, spending, and educational outcomes. Olanrele[33] similarly analyzed how electrification impacts rural households' employment growth. According to the report, electricity considerably increases the employment of women. According to Akpan *et al.*,[30] businesses in communities with access to the power grid are 16.2% more lucrative on average than businesses in communities lacking access. Microbusinesses are also more successful when backup electricity is provided by generating sets.

According to Khandher *et al.*,[34] rural electrification (RE) increases labour supply, household income, and consumption.[31,33–35] However, wealthier rural households receive a larger share of the benefits, while poorer households use electricity less frequently. Khandher *et al.*[34] reported that a limited supply of electricity caused by frequent power outages has a negative impact on both residential electricity connection and consumption, lowering the predicted benefits of RE. The study by Khandher *et al.*[34] substantiated that grid electrification has a significant impact on household welfare while Diyammi and Mkude[36] found that household welfare and rural electrification have a considerable impact on job creation and employment prospects. The study further revealed that electricity boosted businesses including stores and kiosks, supermarkets, dining establishments, and hair and beauty salons. Rural electrification in Tanzania made living simpler and more enjoyable by enabling businesses and kiosks to operate even during the night.

In Peru's electrified districts, rural electrification increased access to essential healthcare services. Additionally, it improved communication, information availability and accessibility.[36,37] This contributed to poverty alleviation, improved healthcare, and bridging the rural-urban growth divide. According to Fetter and Usmani,[38] India's rural electrification decreased the likelihood of witchcraft accusations because of better public and home illumination. According to Ijoma,[39] rural electricity encourages women to work by relieving them of routine responsibilities like fetching firewood. Instead, they made use of the extra time to make money, boosting the household's income. Additionally, the use of electricity reduces indoor air pollution, which has an impact on human health, including lung function.[40] Undoubtedly, electrification is crucial for advancing a country's development. Fig. 1 depicts the presumed effect of rural electrification (RE) on household welfare improvement (HWI). Improved household welfare was determined by employment opportunities available, household income, asset ownership, and access to social services (education and health) as illustrated in Fig. 1.

Furthermore, poverty endures in most rural households.[31,35] A crucial question to be answered is, to what extent does rural electrification impact household welfare? Previous researchers,[4,31,35–37,40,41] investigated the effects, obstacles, and income-generating activities established following rural electrification. This is attributable to the fact that there is limited empirical evidence demonstrating the implications of rural electrification on employment, household income, education, health, and asset ownership among Tanzanian residents,[31,35,36] a gap in the literature that the current study attempted to bridge. The scope of this study was to assess how rural electrification affects the household welfare improvement in Tanzania, using the Mbulu district as a case study. The present study was conducted to determine the effect of rural electrification on (i) employment opportunities, (ii) household income, (iii) asset ownership, and (iv) access to social services.

2. Materials and methods

2.1. Population and sampling

The target population included heads of households from five[5] selected wards in the Mbulu District namely: Gendahu, Ayamaami, Ayamohe, Endagikoti and Sanu Baray. A total of 180

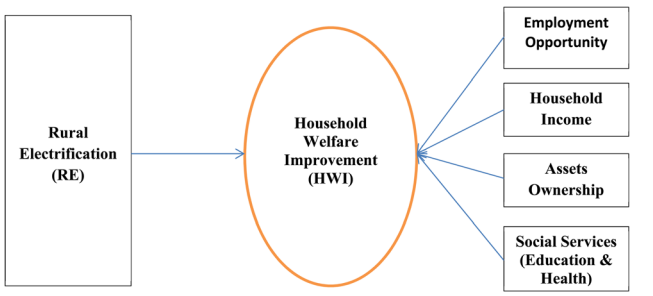

Fig. 1 A conceptual framework of the effect of rural electrification on household welfare improvement.

household heads were conveniently selected from households with and without electric connectivity, who were willing to participate and were readily available during the data collection period of the study.

2.2. Study design

The descriptive cross-sectional design was used in the study since it allowed for the collection of detailed information at a specific moment in time. It allowed for the identification of variables related to rural electrification and the enhancement of people's livelihoods. This design was also suitable for the inquiry since it is cost and time-effective.

2.3. Data collection

Questionnaires, Focus Group Discussions (FGD), and in-depth interviews were used to obtain the data that informed this study. While focus groups and interviews were used to get qualitative data, questionnaires were employed to gather quantitative information. In-depth information was gathered through interviews and focus groups to augment the questionnaire, which is the essence of heterogeneous data-gathering methodologies.

2.4. Validity and reliability

The validity of this study was ensured by the accurate development of research instruments based on the study's objectives. Prior to data collection, external experts in the field were approached to review the instruments against the research objectives and provide feedback for further refinement. Following the completion of a pilot study, questions discovered to be vague were modified to better meet the study's aims. Furthermore, the utilization of various instruments and adaptations of questionnaires from prior similar studies contributed to the study's reliability.

2.5. Ethical consideration

All ethical norms were observed by the researchers during data collection, presentation, and discussion. The researchers secured participation consent from participants after providing basic information regarding the study and its purpose. Confidentiality was also protected by informing respondents and ensuring that their personal identity was concealed. Anonymity was strictly observed throughout the data collection, processing, and interpretation processes. Furthermore, the researchers preserved the participants' dignity, privacy, safety, and fairness.

3. Results and discussion

3.1. Types of a household's business investments before and after rural electrification

The study aimed to know if there were any differences between business investment types before and after rural electrification. According to the study findings (Table 1), households used old diesel grain mills before electrification, but afterwards switched to electric motor-powered mills since firms transitioned from using diesel to electric engine machinery. Also, in irrigation, the majority of agricultural proprietors formerly employed manual methods of irrigation; however, with electrification, they shifted to electric water pumping systems to save time, serve more clients, and increase revenue. Additionally, before electrification, the majority of carpentry workshops operated manually and following electrification, electric carpentry was used, and even the number of carpenters increased. The study further found that before electrification, most business owners, especially women, baked their products using traditional methods (used charcoal and firewood); however, following electrification, they began using baking machines, and currently, quality bread is accessible even in small towns. Furthermore, many alcohol businesses specialized in local brews commonly known as *chang'aa* and the native banana brew prior to electrification; following electric connectivity they have extensively purchased refrigerators and the majority shifted to sell different modern beers such as Safari, Kilimanjaro, Castle Lite, *etc.*

It was further revealed that stationery businesses previously sold books and other stationeries; however, following electrification, printing, scanning and photocopying services are a valuable addition to the majority of stationery businesses in selected Mbulu district wards (Table 1). Welding workshops have also increased and improved dramatically as regards service efficiency following electrification. Both male and female saloons have also adopted modern electric hair trimming and drying machines as opposed to scissors and razor blades previously used to trim hair and sunshine used to dry hair (Fig. 2). These findings are in line with those of Kidole (2015) who similarly found that electrified households owned various business ventures such as bars (40.0%), mobile phone charging services (20.0%), shops and iron welding (11.7%), grain milling (10.0%) saloons (3.3%) and CD burning services (3.3%).

These findings were also supported by the village executive officer and as quoted:

"Most of the businesses in this village have expanded their profit margins following rural electrification. Rural electrification has also resulted in increased job creation. We now work smarter and not harder as we use modern machinery to efficiently process our products. This has minimized both production and service costs. It is now possible to watch live local and international football matches in video centers popularly known as "Vibanda umiza" which was impossible prior to electrification. The days when we would just listen to football games on the radio are long gone".

Another key informant was quoted saying:

"In Chumuli, a grain milling business owner has transformed her business by introducing an electric motor-powered milling machine. She has since inspired other entrepreneurs to purchase the machine by enlightening them on the benefits of electrification. There is also another household that incurred high milling costs owing to the old diesel machine they were operating. Though initially, he was reluctant to purchase an electric motor-powered engine, he was grateful for doing so because within a short time span, the positive impact on his life is noteworthy, he has a new motorbike and a new house".

Table 1 Business investment transition and environmental implications[a]

Types of business investments	Before electrification	After electrification	Environmental management and conservation implications
Grain milling	Old diesel machines	Electric milling machines	Reduction in diesel usage and lower emissions
Irrigation	Manual irrigation means	Electric irrigation pumps	Efficient water use and reduced manual labor
Carpentry	Use of generators	Electric carpentry machinery	Less reliance on generators and reduced noise and air pollution
Baking	Use of firewood and charcoal	Electric baking equipment	Reduced deforestation and a lower carbon footprint
Bar	Local brew bars/clubs	Bars with fridges and modern beers	Decreased traditional fuel use and improved air quality
Stationeries	Lack of photocopying and printing machines	Stationeries with photocopying and printing machines	Lower paper waste through digital services
Welding workshops and garages	Local garages	Garages with electric welding machines and other gadgets	Safer working conditions and reduced fuel consumption
Saloons	Solely for plating hair	Saloons with steaming, curling, and hair-drying machines	Reduced waste from non-electric tools

[a] Source: field data (2024).

Similar findings were made in Ghana, which showed that having access to electricity makes it possible to modernize agriculture through the use of electric-powered irrigation pumps which minimizes labour costs and production costs. Increased employment prospects in electrified towns may result from modernizing agriculture and keeping businesses open later, which may improve overall welfare. Similar findings have been reported in Kenya,[42,43] which showed that having access to electricity allows small and micro businesses to use electric tools and equipment, leading to a significant increase in worker productivity (approximately 100 and 200%, depending on the task at hand) and a corresponding rise in income levels (approximately 20 to 70%, depending on the product produced). In addition to increasing the productivity of agricultural activities, access to electricity concurrently enables and enhances the supply of social and commercial services from a variety of village-level facilities (such as schools, marketplaces, and water pumps).

3.2. Income accrued before and after rural electrification

The study also sought to determine any household income disparities before and after rural electrification. The results in Table 2 illustrate that the income accrued was grouped into the following categories: 50 000 to 200 000; 201 000 to 400 000; 401 000 to 600 000; 601 000 to 800 000; 801 000 to 1 000 000, and 1 000 001 and above per month. The income is presented in Tanzanian shillings (Tsh) (1 USD is equivalent to 2200 Tsh). The results demonstrate that 113 (30.0%) respondents earned less than 200 000 in monthly income before electrification which

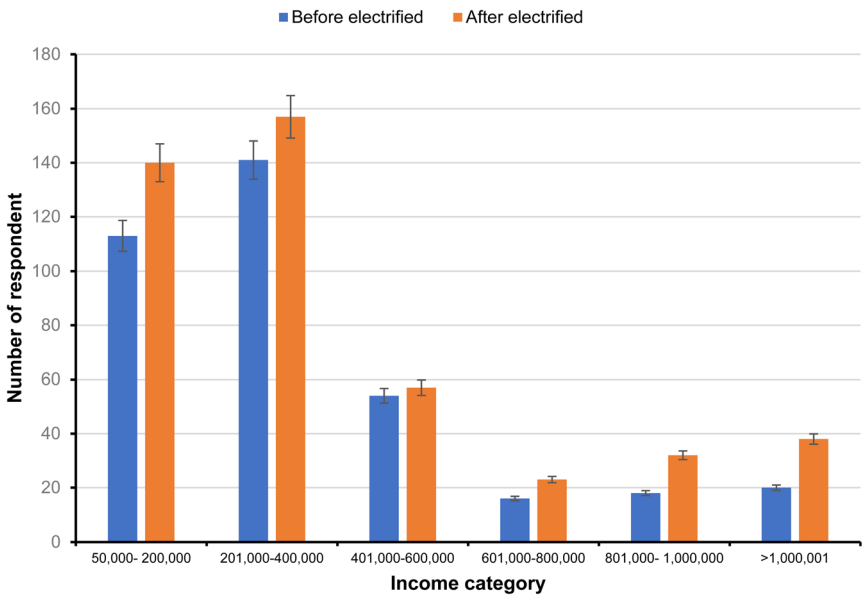

Fig. 2 Household income transformation after rural electrification in the Mbulu district (Source: Field Data, 2022).

Table 2 Respondents' monthly income before and after rural electrification

Respondents' income accrued	Before electrification	%	After electrification	%	%Change
50 000–200 000	113	31.22	140	31.32	19.29
201 000–400 000	141	38.95	157	35.12	10.19
401 000–600 000	54	14.92	57	12.75	5.26
601 000–800 000	16	4.42	23	5.15	30.43
801 000–1 000 000	18	4.97	32	7.16	43.75
1 000 001 and above	20	5.52	38	8.50	47.37
Total	**362**	**100.00**	**447**	**100.00**	

increased by 7% after electric connection, 141(37.0%) said their income ranged between 201 000 and 400 000 before electrification but increased by 4.2% after electrification, 54(14.3%) earned a monthly income between 401 000 and 600 000 which increased by 3.4% upon connectivity, 16(4.0%) revealed that their monthly income ranged from 601 000 to 800 000 before electrification which increased by 2.0%, and 18(5.0%) earned a monthly income of 801 000 to 1 000 000 which increased by 3.0% after electrification. Similarly, 20(6.31%) previously earned more than 1 000 000 in monthly income which increased by 3.79% (Table 2).

These results are consistent with the findings by Kidole[44] that there were statistically significant income ($P < 0.05$) variations between families with grid electrical services and those without, with household annual earnings ranging from 800 000 Tshs to 46 000 000 Tshs. Additionally, supporting the study's findings,[31,34,40] concluded that brighter illumination was significantly associated with increased revenue, which was attributable to the extension of business hours through the night. The author provides examples of tailors in Bangladesh who put in four extra hours of work and reported a 30% rise in their income.

The above findings are in line with those established through interviews as one ward officer remarks:

"…I'm glad that electricity has surged household income. Electricity helped households modernize their businesses, particularly with electric water pumps, milling machines, and modernized saloons. By mainstreaming electricity in their business operations, business owners increased their income and were able to invest in, profit from, and grow their businesses…"

These results are consistent with those of Chaplin (2017), who discovered that rural electrification increases the labour supply of men and women, girls' and boys' enrolment in school, and household income and spending, and decreases poverty. However, the larger share of benefits is for wealthier rural households, while the poorer ones use electricity less frequently. The study goes on to assert that households with access to electricity had higher gross incomes than households without access. Similar findings were made in[45] which showed that households without power connections typically use 1.5 liters less kerosene per month than homes with electricity connections. Additionally, households without access to electricity spend 0.92 USD more each month on cell phone battery recharges than households with access to microhydroelectricity.

3.3. Household welfare before and after rural electrification

The current study examined the difference in household welfare before and after electrification. Household welfare was determined by the ability to acquire basic needs such as food, shelter, education, healthcare, and asset ownership.

3.3.1. Living conditions. According to the study's findings on living circumstances, 36.4% of respondents indicated that their homes had mud floors before electrification, and 30.7% said their walls were unplastered. This shows that their living conditions were extremely poor (Fig. 3). The study discovered that following electrification, respondents improved their living circumstances. On the other hand, 11.3% of the respondents reported that they had mud floors after electrification because they changed the method, they were conducting business, and 7.6% had unplastered walls after electrification. However, they were able to renovate their homes since they had access to basic necessities (such as food, shelter, and clothing) and had their floors cemented, walls plastered, and roofs covered in iron sheets. The survey also discovered that after electrification, the welfare of respondents' households improved over time. This was evident throughout the interview as one respondent shared the following remarks:

"…Before electrifying my business, times were tough, and I had a terrible time paying for basic essentials for my family. Additionally, the firm wasn't performing properly. But as of right now, I've been successful in growing my business, and I can see improvements in the welfare of my family as a result of my ability to take care of practically all of their requirements".

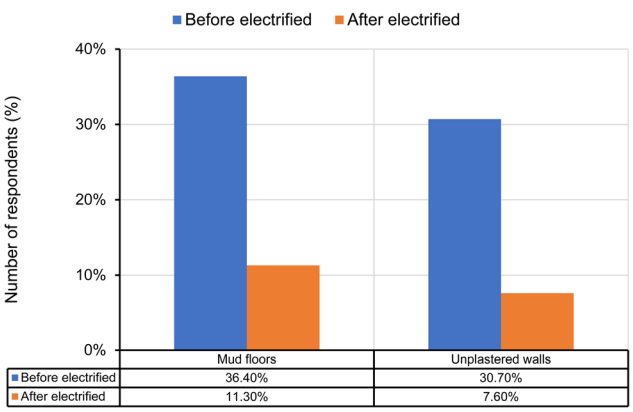

Fig. 3 The changes in house living conditions in the studied population before and after rural electrification (Source: field data (2022).

Another interviewee remarked: *"The electrification that was completed a few years ago has been remarkably resourceful and has boosted my profits within a short period. I faced numerous obstacles prior to electrification as my business wasn't expanding, which had a negative impact on my family's well-being. Due to the success of the business following electrification currently, it is easy to provide for my family's necessities…"*

Zaman (2000) similarly found that prior to rural electrification, low-income households were unable to meet their basic requirements for clothing, food, and shelter. Additionally, Town and Zone (2014) discovered that the electrification of enterprises had a clear potential to boost household livelihoods.

3.3.2. Education status before and after electrification. According to the survey, merely 70.6% of the respondents' children were registered in government schools following electrification, compared to 57.1% of the respondents' children who attended government schools prior to having access to electricity (Fig. 4). A further finding of the study was that, whereas 30.8% of the respondents enrolled their children in private schools after electrification, only 11.1% of respondents did so before electrification. The results suggest that after electrification, the educational standing of the respondents' children has improved, as parents can now afford to buy textbooks, pay school fees, enroll their kids in private schools, and pay for transportation to and from school. This indicates that as a result of improved household welfare, the extra money made from their modernized enterprises was prioritized in the pursuit of quality education.

The study is backed up by[44,45] making the case that modern energy sources are necessary to raise living standards by generating employment and increasing productivity. Additionally, the energy source delivers cleaner fuels for cooking and heating as well as lighting for houses. Thus, the study findings highlight that only if energy is accessible to everyone will important aspects of human welfare such as living a long and productive life, being in good health, having access to knowledge and educational opportunities, and having enough money to meet their basic material and aesthetic needs improve.

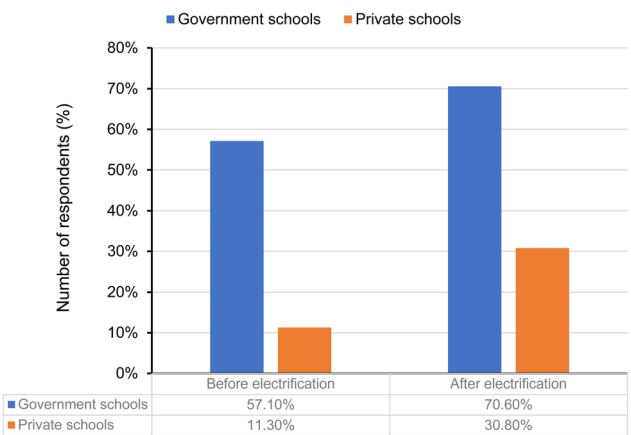

Fig. 4 Respondents' children's school enrolment before and after electrification (Source: Field data (2022)).

3.3.3. Access to healthcare services. According to study results, 40.7% of the respondents lacked access to medical services like X-rays and ultrasounds prior to rural electrification. However, after electrification, most respondents were able to access better health care because hospitals are now using contemporary medical technology to provide services (Table 3). Additionally, just 13.2% of the respondents had access to medication before electrification, compared to 36.2% after electrification. The results suggest that the ability to pay for medical services was improved since electrification had allowed them to grow their businesses and make more income, and having a high income increased their ability to pay for medical costs.

These results support those of Matimbwa and Kipilimba,[35] where it was shown that electricity enables rural households to engage in income-generating activities by supplying lighting that lengthens the workday and supplying power to machines that boost production and productivity. Additionally, it was discovered that rural electrification enhanced health by enabling health clinics to refrigerate vaccinations, run medical equipment, and administer treatments after sundown, as well as by powering equipment for pumping and treating raw water. Additionally, schools are lit by rural power, allowing students to study after hours and improving their employment prospects. In addition, it was discovered in an interview that most respondents had better access to healthcare services because they could afford subscriptions to health insurance programs like the Community Health Fund (CHF). One interviewee particularly remarked that;

"…Rural electrification has aided me in accessing quality health care owing to increased profits. As a CHF member, I now use TIKA (TIBA KWA KADI), for which I just pay 10,000/= per year. As a result, my entire family has easy access to medical care at the nearby public hospital…"

3.3.4. Food security status before and after electrification. According to the survey, 7.6% of the respondents were purchasing food before rural electrification, compared to 29.6% of respondents who did so after electrification. The same study found that 17.6% of respondents employed enhanced farming inputs after electrification, compared to 8.8% of respondents who did so before electrification. Additionally, 16.4% of respondents reported having pest problems following rural electrification, compared to 23% of respondents who had pest problems prior to electrification. This shows that respondents' farming pursuits were hampered by input costs prior to electricity, which resulted in limited agricultural engagement, thus requiring them to purchase food for their households. However, as rural areas were electrified, people could afford the costs of farming inputs and started to grow crops, which made food more accessible. Additionally, they were able to purchase pesticides after electrification since fewer respondents reported being bothered by pests (6.6%) after electrification.

In a comparable direction,[33] showed that customers with electricity could afford more nutritious and diverse meals than their peers who lacked access to electricity owing to increased income. Additionally, households that have access to

Table 3 Access to quality healthcare services as a result of rural electrification[a]

Response item	Before electrification	After electrification
Access to modern healthcare equipment	40.7%	48.9%
Ability to pay for medicine	13.2%	36.2%

[a] Source: field data (2024).

microcredit are more inclined to increase their ability to produce food by sowing quality seeds and using enhanced technology.[34,36,38]

In support of the above, one interviewee commented that;

"…Before electrification, my household income was quite low and I couldn't afford to buy all the food my family needed. As a result, we were accustomed to eating the same inexpensive foods every day, but thanks to a rise in revenue from my small business, we are now able to eat a variety of foods…"

3.3.5. Variations in assets owned before and after electrification. According to the study, 9.9% of respondents still live in mud houses after electrification, compared to 22% of respondents who did so before. This suggests that respondents improved the quality of their construction and home renovations in order to increase household welfare. The outcomes are consistent with[12] findings, which showed that customers had entirely exited poverty by owning valued productive assets like machinery, vehicles, cattle, and improved homes. Additionally,[46] showed that clients of rural electrification had access to more household assets than non-clients, including mattresses, radios, stoves, and beds. Similar findings were revealed during the interview as one interviewee shared that:

"…Through the profit I get from my business as a result of electrification, I have been able to buy household furniture including a refrigerator, I now make ice cream and sell it to students, which supplements my household income, this is an addition to my main business…"

Regression analysis results support the previous findings, as shown in Table 4 below, where it was discovered that rural electrification positively affects changes in business investment, income earned, and household wellbeing. The results demonstrate that rural electrification has a greater significance ($P < 0.05$), impact on income accrued household welfare in terms of their capacity to afford living expenses, as well as their ability to access education, healthcare, and land ownership (Table 4). The study also discovered that rural electricity helped households shift their line of business. These results suggest that the majority of the households' income increased as a result of rural electrification because businesses changed to a more modernized model, which enabled their income to increase and improved their capacity to pay for living expenses in various ways. These results are consistent with those of[47,48]

3.4. The influence of rural electrification on environment management and sustainability

Rural electrification has played a crucial role in advancing environmental management and sustainability in the Mbulu District by addressing several key areas as stipulated below and in Fig. 5.

3.4.1. Reduction of deforestation. The results indicate that 20% of households reported that, prior to electrification, many

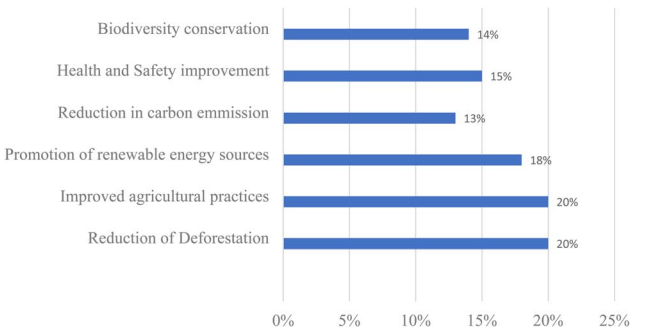

Fig. 5 Influence of electrification on environmental management and sustainability.

Table 4 Regression output of how rural electrification impacted different studied household parameters

Coefficients[a]

Model		Unstandardized coefficients		Standardized coefficients		
		B	Std. Error	Beta	*t*	Sig.
1	(Constant)	1.773	1.665		1.064	0.289
	Business investment	0.002	0.044	0.004	0.056	0.004
	Income accrued	0.493	0.045	0.709	10.852	0.000
	Households' welfare	0.072	0.051	0.092	1.409	0.003

[a] Dependent variable: household welfare improvement.

in the Mbulu District relied heavily on firewood and charcoal for cooking and heating, which contributed significantly to deforestation. However, with the advent of electricity, there has been a noticeable shift towards the use of electric cooking appliances and lighting. This transition has alleviated the pressure on local forests, aiding in their preservation. Similar results were obtained by Tanner and Johnston[49] who pointed out that the move to electricity has not only reduced deforestation but also positively impacted the local environment by promoting biodiversity conservation and the sustainable management of natural resources.

3.4.2. Improved agricultural practices. The results indicate that 20% of households reported that the introduction of electricity has facilitated the adoption of modern agricultural equipment and irrigation systems in the Mbulu District. These technological advancements have significantly improved farming efficiency by reducing water waste and enhancing crop yields. With more precise control over water usage and consistent access to power for processing and storage, farmers are increasingly able to implement sustainable practices.[36] These practices contribute to soil conservation and minimize the environmental impact of agriculture, promoting a more sustainable and environmentally friendly approach to farming in the district.

3.4.3. Promotion of renewable energy sources. The results suggest that 18% of households reported that the rural electrification initiative in Mbulu has significantly fostered the adoption of renewable energy sources, particularly solar power. Solar panels have been strategically installed across various communities, thereby diminishing the dependency on diesel generators and other fossil fuel-based energy sources. Similarly, Pandiyan *et al.*,[45] posited that this transition to renewable energy has not only curtailed carbon emissions but also ensured a sustainable and dependable energy supply for rural households and enterprises. The initiative exemplifies a pivotal step towards environmental stewardship and energy security in the district.

3.4.4. Reduction in carbon emissions. The results suggest that 13% of households indicated that the shift from traditional biomass fuels to electricity, facilitated by rural electrification in Mbulu, has precipitated a marked decrease in carbon emissions. This transition has not only lessened the reliance on wood and charcoal as primary energy sources but has also significantly enhanced indoor air quality. The resultant improvement in air quality has contributed to better health outcomes, notably by reducing the prevalence of respiratory ailments associated with the inhalation of smoke and particulate matter.[36]

3.4.5. Health and safety improvements. The results indicate that 15% of households reported that electrification has led to the adoption of cleaner cooking technologies, reducing indoor air pollution and associated health risks. Moreover, improved lighting and access to information have enhanced safety in rural communities, allowing for safer navigation after dark and better access to health information through the radio and television.

3.4.6. Biodiversity conservation. The results indicate that 20% of households reported that the reduction in deforestation and the promotion of sustainable land use practices have directly benefited biodiversity in the Mbulu District. By preserving forests and natural habitats, rural electrification has supported local conservation efforts, ensuring that diverse plant and animal species continue to thrive in the district. Thus, rural electrification in the Mbulu District has had far-reaching effects on environmental management and sustainability, fostering a healthier, more prosperous and environmentally conscious community. These changes have not only improved the quality of life for residents but also contributed to the long-term preservation of the district's natural resources.

4. Conclusion and policy implications

The study found that households in Mbulu were engaged in a variety of business ventures, including the use of electric engine milling machines, electric pumping machines, modern saloons, modern bars, baking, and stationery with scanners, photocopying machines, and carpentry which significantly increased and improved after rural electrifications. The income earned before electrification was lower compared to that obtained after the rural electrification program. Furthermore, the field survey found that households' well-being has increased in terms of access to better healthcare, education, food security, and living conditions. As households' access to superior education increased because some committed their children to private schools, so did their capacity to purchase both food and healthcare services. They transitioned from mud houses to nice dwellings with plastered walls, which is to say, their living conditions were enhanced. The result of this study is applicable to policymakers and other stakeholders, including the government, to continue empowering household livelihoods in Tanzania's rural areas. The findings of this study demonstrate unequivocally how rural electrifications improve the livelihoods of rural households by having a beneficial impact on employment, income, asset ownership, and social services, all of which are issues that were not well covered in previous investigations. The study findings will be conceptually applied in future investigations in other rural areas with similar features to the Mbulu district. As recommended therefore, government agencies should provide electricity in rural areas to promote the use of electricity for commercial and residential purposes, which would enhance the economic security of rural communities and result in a sustainable standard of living. The present study used only Mbulu as a case study, and thus it is better for the same kind of study to be conducted in various districts to extend the validity of the study conclusion and recommendations in other applicable areas.

Ethics approval

All ethical approvals and permits were obtained from the relevant organization and authorities in the study area.

Consent to participate

Consent to participate was obtained from all participating respondents before being engaged in the study activities.

Data availability

The datasets used and analyzed during the current study are available from the corresponding author, upon request.

Author contributions

H. M. and M. E. M.: conceptualization and methodology; H. M.: writing original draft preparation; H. M. and M. E. M.: writing research paper and editing. All authors have read and agreed to the published version of the present paper.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in the paper.

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