Community resilience in Bondo community, Southern Malawi: balancing energy, water and biodiversity

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Abstract

Purpose – This study aims to investigate the intricate relationships between a community energy system, water resources and biodiversity conservation, with a specific focus on augmenting community energy resilience in Bondo. The primary objective is to gain an in-depth understanding of how community members perceive and experience the challenges related to balancing the often-conflicting demands of energy, water and biodiversity conservation within this context.

Design/methodology/approach – The research uses a qualitative approach to unravel the multifaceted dynamics of community energy systems, water resources and biodiversity conservation in Bondo. Data were collected through focus groups and direct observations, enabling a nuanced exploration of community perspectives and lived experiences. The subsequent analysis of this qualitative data follows established thematic analysis procedures.

Findings – The study's findings shed light on the formidable barriers that impede rural communities in Malawi from accessing electricity effectively. Even in communities fortunate enough to have electricity connections, the lack of knowledge regarding productive electricity use results in community energy systems

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operating at significantly reduced load factors. Furthermore, the intricate challenge of managing a biodiversity hotspot persists, exacerbated by the densely populated peripheral communities' continued reliance on forest, land and water resources. These activities, in turn, contribute to ecosystem degradation.

Originality/value – In a context where government-led management of forest reserves and game reserves has not yielded the expected results due to a multitude of factors, there arises a compelling need for innovative approaches. One such innovation involves fostering partnerships between the government and experienced trusts as lead organisations, providing a fresh perspective on addressing the complex interplay between community energy systems, water resources and biodiversity conservation. This novel approach opens doors to explore alternative pathways for achieving the delicate balance between human energy needs and the preservation of vital ecosystems.

Keywords Hydropower mini-grid, Resilience nexus, Thematic analysis, Biodiversity hotspot

Paper type Research paper

1. Introduction

The challenge of sustainably managing a hydropower energy system within biodiversity hotspots lies in the complex interplay between electricity management, water conservation and biodiversity preservation, all influencing livelihood options (Liu, 2016; Barbarossa *et al.*, 2020; Barbarossa *et al.*, 2020). The interconnected nature of these elements, coupled with the imperative of bolstering community resilience, necessitates careful equilibrium and synergy to ensure that fulfilling one or more of these aspects does not detrimentally impact the others. However, there is a tendency to focus on access to electricity because of its transformative nature. Access to electricity has a transformative effect on vulnerable communities, contributing to sustainable development.

Studies such as Clark (2021) and Saing (2017) report that electricity access positively influences female employment and extends working hours for both genders. In other studies, in Asian countries such as Bangladesh, Vietnam and India, electricity access has led to positive outcomes, including increased study time, enrolment, household incomes and consumption (Saing, 2017). A study on the Light for All (*Luz para todos*) program found that electricity access, coupled with cross-subsidies, resulted in an income increase of up to 250% (Da Silveira Bezerra *et al.*, 2017). In Senegal, innovative policies, including cross-subsidies for electricity tariff reduction accompanied rural electrification, lead to a threefold increase in the country's GDP per capita (Trotter, 2016). A World Bank (2012) study revealed that an electrification initiative, coupled with the development of light industrial zones and business training, led to the establishment of 550 companies and the creation of 1,970 employment opportunities in Ghana.

The World Bank (2017) elucidates that the targets of SDG 7 are interconnected with 125 of the 169 targets across all SDGs. It is widely agreed that a significant factor contributing to community vulnerabilities is the lack of electricity access (Garniati *et al.*, 2014; Clemens *et al.*, 2010; Bruderle *et al.*, 2011). This underscores the importance of electricity and encourages exploiting local resources, such as developing hydropower plants in biodiversity hotspots.

There is need to ensure the continuity and affordability of electricity for low-income households to foster social, economic and environmental development presents challenges. The mere provision of electricity has been insufficient to promote sustainable development in target areas (Garniati *et al.*, 2014; Bruderle *et al.*, 2011). A more comprehensive approach involving various stakeholders and considering the target community's self-perception and circumstances is necessary to complement electricity access. Despite such interventions, beneficiaries often rely on natural resources from forests, water and land for their livelihoods. The interconnection of the community's livelihood, biodiversity, water and energy necessitates careful balancing. This study aims to enhance understanding of the nexus approach in managing water, energy and biodiversity to minimise their interrelated impacts.

With its Bondo Mini-Grid located near or within the biodiversity-rich Mulanje Mountain, the Bondo community provides an opportunity to explore this interconnectedness. While the Bondo mini-grid is an intervention to enhance the community's resilience, it should not compromise watershed management and biodiversity conservation. Understanding the energy system's impact on biodiversity conservation, community resilience and watershed management is crucial and can be effectively studied within the nexus approach.

2. Literature review

2.1 Community resilience

Community resilience is a highly complex concept. No wonder a review of 62 publications by Patel *et al.* (2017) came up with 57 unique definitions. The difficulty in defining community resilience is that the term can be conceptualised differently, whether as a process, an outcome, or just a range of attributes (Schmidt-sane *et al.*, 2021). Without labouring on the actual or consensus definition, the concept of resilience has, in this case, been contextualised within the development agenda and before disaster or disruption. Within the development agenda, resilience is an essential conceptual tool in understanding and appreciating how individuals, households and communities respond and adapt to many changing shocks and stresses that have a bearing on their livelihood outcomes (Jones and Tanner, 2017). It is not enough to cope as human systems such as communities must undergo continuous transformations, system integrity, self-organising and learning (Sharifi and Yamagata (2016). Jones and Tanner (2017) state that human systems' resilience should encompass the capacity to absorb change, preparedness and contingency, innovation and learning, renewal, reorganisation and development. Meng *et al.* (2018) believe that human systems' resilience and adaptability are embedded in the mental and physical health of the people concerned. This is true as human systems should have many attributes to mitigate, adapt and transform within the ever-changing environments. These attributes include local strengths and resources, the community's skills and knowledge, capacity, sufficient infrastructure and services and natural assets. With electricity as a tool for building resilience, communities or households are expected to be able to diversify their livelihood away from being dependent on climate-related options. Failure to use electricity as an essential economic opportunity means the community still relies on natural resources such as water and biodiversity in an unsustainable manner.

2.2 Nexus approach

Mohtar and Lawford (2016, p. 193) define nexus as a connection or link – often causal – between a group or a series of objects and ideas. Much as focused expertise and management are still important, the interconnectedness of global challenges within food security, health, education, energy, biodiversity protection and climate change require an integrated or nexus approach (Liu *et al.*, 2018). The nexus approach is a complicated phenomenon as it simultaneously tries to satisfy two or more intertwined or interconnected sectors. Many authors agree that a better understanding of the nexus concept is through stakeholders' engagement and dialogue (Flammini *et al.*, 2014; Aboellnga *et al.*, 2018; Siala *et al.*, 2017; Mohtar *et al.*, 2015). The alignment of different goals and interests of stakeholders within the concept of nexus requires multi-disciplinary and trans-disciplinary approaches. Stakeholder engagement should incorporate local communities that influence or are influenced by the areas in question. By involving these communities, they can leverage their unique and experiential knowledge. This approach ensures that these vulnerable communities' actual needs, priorities, and perceptions are considered when resilience options are discussed.

2.3 Biodiversity hotspots within energy generation

There is enormous concern about rural electrification through hydropower plants, which mostly take advantage of river basins that are rich in plant and animal species (Basso and Bakken, 2022; Guo *et al.*, 2007). The danger these hydropower plants pose are mitigated by mandatory Environmental Social Impact Assessment for more significant projects (Uprety *et al.*, 2010). This is not the case with community energy systems, as they do not have such stringent requirements. The areas that are rich in plant and animal species, especially if the species are endemic, near-endemic or under threat of extinction, are called biodiversity hotspots (Costello *et al.*, 2022; Merritt *et al.*, 2019). Much as the biodiversity hotspots are a small fraction of the earth, 1.4%, they are home to over 60% of all plants, birds, mammals and reptile species found on the planet (Merritt *et al.*, 2019). The primary concern is that the hotspots continue to decrease through encroachment and bushfires. At the same time, species in the areas are impacted by human activities of overexploitation, hunting, fishing, water abstraction, nutrient enrichment, pollution, introduction of evasive species, pests and diseases and climate change leading to habitat loss and fragmentation (Costello *et al.*, 2022). Biodiversity hotspots are, therefore, in urgent need of protection. These energy systems that share their catchment areas with biodiversity hotspots require a deeper understanding of the livelihood options of the surrounding communities concerning watershed management and biodiversity conservation (Japoshvili *et al.*, 2021).

2.4 Mulanje Mountain as biodiversity hotspot

Bondo Community is close, if not within, Mulanje Mountain Forest Reserve (MMFR). The reserve, located in Southern Malawi, has national and global environmental significance for its richness in biodiversity (Development Alternatives Inc, 2006). The mountain's high altitude intercepts moist southeast winds from the Indian Ocean; hence, the summit receives over 4,000 mm of annual rainfall (Borgstein, 2017). The size is 650 square kilometres, and the summit rises to 3,002 m above sea level against the surrounding of 650 m above sea level. The mountain has afro-montane forests near the summit, a habitat of many endemic fauna and flora species, many of which are endangered or threatened by extinction (World Bank, 2001) (Malawi Government, 2017). Of the many species of the mountain's forest reserve, those recorded include 1,300 plant species, 250 butterflies, 180 birds, 55 reptiles and 32 amphibians (Wisborg and Jumbe, 2010). Of the recorded species, 40 plant species are endemic, 8 are endemic butterflies and 8 are near-endemic birds. The other endemic species found on the mountain are two dwarf chameleons, two geckos, one skink, one lizard, one frog sub-specie, one squeaker frog and one ridged frog (Thompson (2013)). Numerous snake species and additional gecko species, greater hamster rats and various sub-species of monkeys on the mountain have been reported to be near-endemic. Some birds found on the mountain are considered threatened species (World Bank, 2001). Wisborg and Jumbe (2010) report that the mountain was also home to large animals such as eland, but only blue duiker, bushbuck, red duiker and klipspringer, which can hide in steep slopes, have remained. Such a variety of species, some endemic and near-endemic, make the mountain unique and attractive to biological conservationists and evolutionists. With such large numbers of near-endemic and endemic species and the many communities within the area, the conservation of biodiversity and sustainable use of biodiversity resources by the surrounding community is a priority.

The other renowned aspect of Mulanje Mountain is the presence of the endangered Mulanje Cedar. The tree species *Widdringtonia whytei,* endemic to Mulanje Mountain, first noted by Scottish missionary Robert Cleland in 1888 and then described by Whyte in 1893, was named Cedar by Rendle in 1894 (Bayliss *et al.*, 2007; Borgstein (2017). Mulanje Cedar is

valued for its fine timber, attractive fragrance, and pest resistance from termites, fungi, and borer. The tree species have significantly declined due to illegal timber logging (Borgstein, 2017). Several efforts are in place to protect the mountain's cedar and other unique species, one of which is the application made for the Mulanje Mountain Forest Reserve in 2000 to be included in the World Network of Biosphere Programme. The application submitted to UNESCO for a World Heritage Site aimed to protect the mountain's ecosystem, and the UN would have assumed the mandate to take legal action if the ecosystem is threatened (Bayliss *et al.*, 2007).

The high rainfall combined with the unique rock structure of the mountain makes Mulanje Mountain a vital freshwater catchment area, energising nine perennial rivers. The water is used for domestic and commercial uses such as hydropower resources and irrigation of tea estates downstream, apart from providing necessary habitat for many unique and endemic species. The uniqueness of the mountain is appreciated through the many recognitions by various designated institutions (Wisborg and Jumbe, 2010) as follows:

- Mulanje Mountain Forest Reserve (declared 1927 by the then colonial government);
- Mulanje Mountain Global Biosphere Reserve (MMGBC) (declared in 1990 by UNESCO;
- recognised by the World Wildlife Fund (WWF) as one of 200 ecoregions of particular importance for biodiversity conservation and an Afromontane Regional Centre of Endemism;
- recognised by *the* International Union for Conservation of Nature (IUCN) as an International Centre of Plant Diversity;
- recognised by Conservation International as an Eastern Afro-Montane Biodiversity Hotspot; and
- World Heritage Site (application prepared by MMCT and a consultant).

The abundant rainfall on the mountaintop reportedly sustains nine perennial rivers and numerous streams (Taulo *et al.*, 2008). Recently, the hydropower potential of mountain rivers has been harnessed for grid and mini-grid connections. Mulanje Hydro and Cedar Energy have installed 8.2 and 3.2 MW hydropower plants on the Ndidza, Ruo and Mulodza Rivers, all connected to the national grid. This study focuses on the Bondo Community's 220 kW Bondo Mini-Grid, a cascade of three power plants serving over 1600 households, social sectors, and small businesses along the Lichenya River. The Bondo Mini-Grid is a significant initiative for fostering community resilience through power provision for various activities. Its proximity to the mountain offers a crucial area for understanding and managing the interplay between social and ecological systems, including biodiversity management.

3. Methodology

The study was conducted in Bondo Community, located in Mulanje, Malawi. The area is situated close to the Mulanje Mountain Forest Reserve. Bondo Community relies on the resources provided by the mountain, including firewood, water, mushrooms, potential for hydroelectricity, and farmland. Bondo was chosen as the study site due to the characteristics associated with biodiversity conservation, community livelihoods and proximity to a local hydropower plant.

The participants were selected from the Bondo Community using purposeful sampling. Purposeful sampling is a non-probability technique. It involves the researchers leveraging their knowledge to select specific participants based on attributes conducive to achieving the study's goals and addressing the research questions. Ethical approval for the research

was obtained from the Mzuzu University Research Ethics Committee in November 2021. The study collected qualitative data from the participants using focus groups and field observations. Data collection occurred between December 2021 and May 2022, with additional data collected in December 2022.

3.1 Focus group discussions and meetings

The first focus group meeting was with the Mulanje Electricity Generation Agency (MEGA) employees, who manage the mini-grid. This meeting focused on the mini-grid's history, challenges, opportunities and prospects. The second focus group meeting had an attendance of about 20 participants, which included community members, including some village leaders and the representations from institutions, which included the Civil Society Network on Climate Change (CISONECC), Renewable Energy Industries Association of Malawi (REIAMA) and OXFAM. CISONECC is a network organisation for coordinating civil society initiatives for climate change management and disaster reduction, REIAMA is an association with membership from individuals and companies that are involved in the production, supply, importation, installation and servicing of Renewable Energy Technologies in Malawi, while OXFAM is an international NGO that fights inequality and ending poverty and injustices. This meeting focused on the opportunities and challenges faced by the community before and after the introduction of the mini-grid. The third focus group meeting had a diverse participation, including village leaders, members of the Village Electricity Committee, MEGA employees, local businesspeople, religious leaders, health personnel, teachers and researchers. This meeting, which 21 participants attended, took place on 2 December 2022. All focus group meetings were recorded.

3.2 Observations

The observational component of this study focused on various aspects, including local businesses, infrastructure, indicators of livelihood options, terrain features and environmental protection efforts. This observational data was complemented by engaging with stakeholders. Three focus group meetings were conducted with community members, leaders and other relevant stakeholders to enrich our understanding further. Detailed field notes were meticulously recorded based on these observations and interactions.

3.3 Data analysis

The focus group audio recordings were transcribed and imported into NVivo for analysis. Thematic analysis served as the primary analytical approach, involving the generation of initial codes, recoding into higher-order codes, organising these higher-order codes into categories and deriving overarching themes. NVivo was chosen due to its diagramming and code comparison capabilities. Thematic Narrative Analysis was employed to develop regulations, identify relationships among similar codes, form categories and extract themes (Kim, 2015). Ensuring the validity of findings involved inter-coder rating, using an iterative process to converge on similar themes from the data. Data triangulation further enhanced validity, incorporating various sources such as field notes, meeting minutes and transcriptions from focus group discussions to mutually validate findings. Themes play a crucial role in describing phenomena deemed significant to the study (Fuller *et al.*, 2008). Additionally, narrative analysis was combined with thematic analysis. Narrative analysis involves uncovering meaningful stories to understand how individuals make sense of events and their effects (Bryman, 2012, p. 582). The integration of thematic analysis with narrative analysis results in narrative thematic analysis (Butina, 2015). While no standard format for reporting data exists, the study adopts an approach similar to Butina (2015), presenting

observed themes supported by relevant quotes. Including quotes is paramount as it provides tangible evidence of the study's findings.

4. Findings

This section presents findings from thematic analysis using NVivo and field notes documenting the observations made. The results are grouped into four themes. The first theme of *electricity by grid or mini-grid – not an easy path* which is coming from thematic analysis. The second theme of *community resilience at a crossroads of mini-grid and biodiversity* comes from thematic analysis and field notes. The third theme of the *energy, water and biodiversity nexus* comes from thematic analysis and notes from field observations. These themes are expounded below.

4.1 Electricity by grid or mini-grid – not an easy path

The findings are about the community's difficulties with electricity connection. The community's representatives visited ESCOM, a state utility, on how the community could have access to the grid electricity. Extending the grid from the estimated distance of 15 km was prohibitive. The community members had no option but to resign to the fate that they would never have electricity:

> Extending grid electricity from Minimini, the nearest place to have the grid connection, at 15 km, was quoted as K85m (an estimated equivalent of US$613,000.00 then) in 2006. As chiefs, members of parliament and councillors in the area, we sat down to map the way forward but could not come to a solution as the money was so huge. There was no way that such an amount could be raised even with some external connections that were available.

It surprised the community that the representatives of Mulanje Mountain Conservation Trust (MMCT) and the District Council's office brought the idea of generating electricity locally, taking advantage of the Lichenya River in 2007. Considering the importance of such an initiative and that the community members needed electricity so much, community members volunteered land and labour towards the project. The project did not come so quickly; it took seven years, with the first connections happening in 2014. Testimonies were made on how electricity had brought convenience and improved living standards in areas of business, maise milling, education, reduced energy bills and health as:

> Primary schools such as Kabichi and Mabanja could hardly attract teachers before electricity with only 4-5 teachers for all grades from 1 to 8 in total. After electricity, the number of teachers at Kabichi rose to 24

> We were walking around 8 km to access maise mills, which is not the case after electricity [. . .]. In health, there is an increase in personnel, good lighting and refrigeration leading to improved services [. . .] video shows, barber shops and soft drinks being refrigerated are some businesses that have come with electricity.

> Reduced energy bills from K15,000 per month for charcoal to K8,000 with electricity if used for cooking, lighting, phone charging and powering radios and TVs. [. . .] With electricity there has been improvement at the clinic as some medicines are stored at the clinic unlike previously when such medicines were stored at the district headquarters, more than 16 km away.

> When I joined a local school the pass rate was 60% but jumped to 85% in 2016, mainly due to electricity. The pass rate increased further to 100% in 2017. This in line with the government's target that primary schools be able to achieve not less than a 90% pass rate. Teachers were

> indeed refusing to join schools around the area before I joined due to unavailability of electricity and I was compelled because it is my home village, and I needed to contribute.

4.2 Community resilience – at a crossroads of mini-grid, biodiversity and watershed

Establishing the mini-grid in the area aimed to facilitate energy transition and make the community thrive, i.e. the households should be able to gain wealth and possessions, hence reducing dependence on the mountain resources. Primary uses of electricity, such as lighting, charging phones and entertainment, were prominent in the area. Small businesses such as barber shops, video shows and selling refrigerated soft drinks are carried out. What was observed to be so much missing is the Productive Use of Electricity and electric cooking. This can be attributed to the low load factor:

> The normal load is mostly less than 110 kW for all the 1,600 households, including four maise mills running at the same time. The peak load of 110 kW takes place between 5 pm and 9 pm. The off-peak load of 40 kW is mostly recorded during the late hours of the night.

Such low uptake of electricity means there is no productive use in place, and the electric cooking is vividly missing. Such being the case, the community heavily depends on the mountain for firewood and charcoal for cooking, leading to loss of ground cover and felling of trees. All this leads to reduced stability of water flow in rivers (Development Alternatives Inc, 2006). This results in flooding of rivers during the wet season and drying of the rivers in the dry season. The reduced stability of the water flow also leads to slope erosion, resulting in vast loads of silt into the rivers. Hydropower generating capacity is, obviously being reduced in such cases:

> In the dry season, there are continued low water levels over the years, reducing electricity generation [. . .] Maise mills fail to run during the dry season.

> At Bondo 3, the river carried rocks and stones through the penstock to the turbine blades. As these were successfully removed, the turbine has reduced generation capacity as some blades bent.

> Big challenge is siltation and debris accumulation into the river stream.

The lack of PUE means that community members do not use the mini-grid to enhance their resilience. On the other hand, the mini-grid has managed to attract and retain professionals within the health, education and other sectors, which means an increased population. The general population primarily depends on land resources, and the Mulanje district's low land holding size of 0.6 ha per household in 2016 (Malawi Government, 2017) further complicates the existing problems. Such a small land holding capacity means people cannot grow food for their consumption year-round, let alone some cash crops for sale. With no tangible alternatives, community members are forced to look forward to unsustainable livelihood options such as illegal logging of forest trees to have timber, firewood and charcoal burning for home use and sale, bushfires for hunting and encroachment of the forest reserves for farming land. The mini-grid is, therefore, not contributing much to the enhancement of resilience of the community households, hence the continued dependence on scarce land and forest products. Such reliance on the mountain and forest products affects the mountain's and the watershed's biodiversity. The loss of biodiversity impacts the well-being and resilience of the community, especially the disturbance of the watershed, which in turn affects electricity generation. Of course, there are some efforts on conservation, especially by some chiefs around Bondo Community, but the laws, limited enforcement and the fact that the majority are lacking or have no tangible alternatives are not helping much:

> As chiefs, we volunteer to protect the trees but the outdated laws of forest prevent us from enforcing or working better. We can catch a person logging tress and take him/her to the police only to have the person released within days after paying a fine, mainly in a region of K30,000 (US$28.5). The person may even be a danger to us and boast to have come out scot-free. We need to review forest laws.

> There are also challenges with changes of offices within the forestry department. Personnel get transferred so often. MMCT helped construct roadblock to curb the movement of trucks loaded with timber and poles, but trucks are let to pass by forestry personnel.

Much as some hazardous activities are happening, such as the continued cultivation of steep river banks with pineapples flourishing in such areas, some activities take place to preserve the catchment area. Field visits have shown increased planting of trees, reduced logging and taking care of the planted trees on the mountain's slopes around the Bondo area. Unlike the other mountain sections, institutions such as MEGA, MMCT and Sukambidzi Trust support this in Lichenya River catchment areas:

> Companies such as Lujeri are providing a nursery of trees and the community has the duty to plant the seedlings. Trees are grown in catchment area of Lichenya River [. . .] we also need to take care of trees that are available while at the same time planting others.

The other parts of the mountain that had been visited continue to face challenges of environmental degradation due to human activities. One such area is at the intake of the Ruo-Ndiza hydropower plant. The area has very few trees, and others have been logged due to the stamps seen. The region upstream of Lujeri River 2 is also in a bad state, with loggers openly felling trees during the day. There is even a designated place where timber is openly sold. We were told that any attempt to stop people harvesting trees for wood threatens one's life. Such developments may affect the Lichenya catchment area as the mountain is the same.

4.3 Energy, water and biodiversity nexus

Participants were in total support of MMCT entering into an agreement with the Malawi Government. Under such an agreement, MMCT should be given exclusive rights to manage Mulanje Mountain Forest Reserve (MMFR) in partnership with the Department of Forestry. In the current scenario, the sole mandate is with the Department of Forestry (DF), with MMCT in the peripheral or working just like any other institution interested in the sector. Participants believed that DF has its approach of silo-thinking of forest conservation and possibly reforestation only. So far, MMCT's approach has been nexus as all sectors of fauna, flora, watershed and community resilience are supported:

> MMCT is pushing for a concessional agreement with the government so that the institution can have exclusive rights towards the protection of Mulanje Mountain Forest Reserve. A similar arrangement had been made between the government and African Parks in Majete Game Reserve, Kasungu National Park, and Liwonde National Park. The challenge is that the forestry department has mandate of sectoral, i.e. only consider trees while MMCT will have a nexus approach with consideration of forest, water, energy and their interaction.

The proposal for the agreement is modelled on the agreement between the Malawi Government and its Department of National Parks and Wildlife on one hand and the African Parks on the other. The African Parks, also a trust, has recorded some successes in the management of some game reserves and national parks in the country.

5. Discussions

The study's results highlight the intricate relationship between energy access, environmental conservation, community development, and governance strategies. The success of electrification

initiatives depends not only on technical implementation but also on comprehensive strategies that meet local needs, environmental sustainability and community empowerment. The MMCT's nexus approach presents a promising framework for balancing energy access, environmental preservation and community resilience. This requires collaborative efforts and policy adaptations for sustainable development.

The challenges of rural electrification, as highlighted in Bondo, are not unique to Malawi. Many developing countries face obstacles when it comes to making significant progress in this area. However, there are success stories that often emerge from government-led initiatives. For example, Ghana experienced a notable increase in rural electrification from 6% in 1990 to nearly 50% in 2014 under President Jerry Rawlings (Trotter, 2016). Similarly, the former President of Senegal championed rural electrification, witnessing an expansion from 5% in 1997 to 30% by 2010. In contrast, countries like Tanzania and Nigeria have seen tangible outcomes through streamlined regulation and subsidised provisions (Trotter, 2016).

Malawi, on the other hand, lags significantly behind in rural electrification, with only 5.6% in 2021 (IEA *et al.*, 2023). Thus, government-led initiatives are urgently needed to address this issue. However, the development of mini-grids is a promising alternative due to the absence of an enabling environment and inadequate government support. Currently, the entire country is served by only three mini-grids: Sitolo PV, Bondo Hydro and Chipopoma Hydro, whose future remains uncertain due to operational challenges. This situation is in stark contrast to the sentiments of the Bondo community, who, in 2006, could not imagine witnessing electricity in their lifetime.

As the introduction of electricity, there have been notable improvements in education, health care, economic activities and overall living standards. However, we must also acknowledge the challenges faced by mid-grids in areas rich in biodiversity like Bondo. The second theme, "Community Resilience – at a crossroads of mini-grid, biodiversity, and watershed," highlights a significant issue in the impact of mini-grids. While the electrification initiative has brought about significant improvements, the community's limited use of electricity for productive purposes remains a concern. This limitation leads to continued reliance on unsustainable practices such as deforestation for fuel, resulting in harmful consequences for the watershed and biodiversity. The lack of productive electricity uses and insufficient load factor highlights the challenge of transitioning to sustainable energy practices and the complex relationship between energy access, environmental sustainability and community resilience.

The dependence on natural resources has become entrenched within impoverished communities around Mulanje Mountain. To these locals, biodiversity conservation takes a backseat, with the mountain perceived as vital for their very existence (Borgstein, 2017). The interplay between biodiversity, livelihoods, conservation and poverty reduction is intricate and context-specific. Nonetheless, encouraging strides have been witnessed in conservation efforts around Bondo, unlike in areas devoid of interventions like electricity access.

Effective conservation endeavors necessitate concurrent financial provisions and alternative livelihood options. Governments, as seen in China's intervention along the Yangtze River, have offered cash compensation for encroachment on catchment areas for hydropower. This practice resulted in the conversion of farmland into forests, ceased logging activities, reduced soil erosion and siltation and conserved biodiversity (Guo *et al.*, 2007). However, not all governments possess the capacity for such monetary incentives. Alternatively, market-based approaches should be considered. Interventions aimed at increasing productivity and adding value to local products could foster job creation and augment income generation. Although the MMCT facilitates various livelihood alternatives, Bondo's unfavorable conditions – cold, limited land, steep slopes and high humidity –

hinder their implementation. A viable prospect for Bondo could involve establishing a factory for processing pineapples, leveraging the area's abundance of this fruit. Value addition to pineapples could escalate raw pineapple prices, engender job opportunities throughout the value chain and boost economic prospects for the community.

Malawi's Government has forged agreements with African Parks, granting exclusive management rights over Majete Game Reserves, Liwonde National Park and Nkhotakota Wildlife Reserve. Majete Game Reserve's management by African Parks since 2003 has witnessed significant positive changes. Once labeled an "empty forest" due to rampant poaching, negligible surveillance and zero tourism income under the Department of National Parks and Wildlife, it underwent remarkable transformation under African Parks. The reintroduction of 3,000 animals representing 17 species, including rhinos, elephants, leopards, buffalo, cheetahs and giraffes, sparked a revival (African Parks, 2022). By 2020, the reserve housed over 12,000 large animals and employed 165 individuals, supporting nearby communities through beekeeping, fish farming and solar-powered irrigation schemes. Enhanced ranger numbers and surveillance technology have been instrumental in conservation efforts, curbing human-wildlife conflict. Increased visits to the reserve have bolstered local incomes, benefitting the community. In 2020, approximately US$75,765 was allocated for community support in education, health and agriculture (African Parks, 2022). Though replicating such an arrangement with MMCT's overall control from the Department of Forestry for Mulanje Mountain remains uncertain, the successes of trusts like African Parks underscore the potential for MMCT to effectively manage the mountain reserve in collaboration with the government as part of a private-public partnership.

5.1 Practical implications

The implications drawn from the study underscore a crucial need for a comprehensive and a careful approach to address the challenges posed by rural electrification in Malawi, particularly in the context of communities such as that of Mulanje Mountain that are heavily reliant on natural resources and biodiversity. To begin with, the findings highlight a delicate balancing act between hydropower development, conservation efforts and the livelihoods of communities dependent on natural resources. The initiatives such as mini-grid development and conservation efforts may inadvertently limit communities' access to essential resources, posing a challenge that needs careful navigation. Secondly, the study strongly advocates for a multi-dimensional approach that incorporates policy reforms, community engagement, sustainable economic activities and effective governance. This holistic strategy is deemed essential to address the challenges of rural electrification while simultaneously promoting conservation and enhancing the livelihoods of the communities. The third implication is that the study calls for tailored Strategies. Recognising the diverse local contexts and challenges, the research emphasises the importance of tailored strategies for holistic development. One-size-fits-all solutions may not suffice; hence, there is a call for customised approaches that consider the unique needs and circumstances of each community. The fourth point touches on policy implications. The study identifies crucial policy implications tied to rural electrification challenges in Malawi. It stresses the necessity of well-thought-out policies that foster community engagement, sustainable economic activities and effective governance to address these challenges. The fifth implication is on conservation and livelihood enhancement. Central to the implications is the inseparable link between conservation, electrification and livelihood enhancement. The study urges a harmonious integration of these elements, highlighting the intricate relationship between hydropower development, natural resources, biodiversity and the well-being of the local communities.

The study emphasises the point that successful rural electrification in areas like Mulanje Mountain demands a careful, context-specific and multidimensional approach. By acknowledging and addressing the complex interplay between electrification, conservation and

community livelihoods, there is an opportunity to forge a path towards sustainable and inclusive development in Malawi. Developing countries, such as Malawi, are in desperate need of government funding for key sectors like health, agriculture and education. This makes it challenging to carry out effective conservation efforts. Without external support or arrangements like concession agreements, biodiversity conservation is inadequate. The rare, endemic and near-endemic species of the mountain will continue to decline at an alarming rate. Therefore, it is essential to consider concession agreements with trustworthy and experienced organisations. Additionally, conservation efforts should be combined with empowering rural communities through employment opportunities and diversification of livelihoods.

6. Conclusion

Managing a rural hydropower system in a biodiversity hotspot is complex and full of challenges. The challenges are compounded by densely populated surrounding communities that may underuse the system, thereby limiting their ability to diversify their livelihoods away from dependence on forest, water and land resources. While electricity access can spur local economic development, its impact is limited if not integrated into broader community resilience-building initiatives. This study shows that without collaboration of government departments and private entities, maintenance efforts for biodiversity in a hydroelectric plant area are likely to be inadequate. The lack of surveillance and alternative livelihood provisions for surrounding communities contribute to ongoing environmental degradation. Drawing from the successful management of game reserves in Malawi by African Parks, a shift towards a private-public partnership of electricity projects in biodiversity rich areas is suggested. Such a private–public partnership could involve community members through a trust in collaboration with a government entity. This multifaceted approach would address both community livelihood options and conservation efforts, serves as a promising model for this proposed initiative.

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