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Final Report for the Evaluation of the ENRM Project in Malawi

Volume II: The Weed and Sediment Management Activity, Environmental Trust, and Overall Project Evaluations

September 2022

Anthony Louis D'Agostino, Jacqueline Shieh, and Kristen Velyvis

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Mathematica strives to improve public well-being by bringing the highest standards of quality, objectivity, and excellence to bear when collecting information and performing analysis for our clients. This mixed-methods evaluation reflects the independent assessment of its authors, who have no potential conflicts of interest, to their knowledge, in evaluating the ENRM Project. The evaluation is funded by the Millennium Challenge Corporation, a U.S. government agency.

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ACRONYMS LIST

BEST	Basin Environmental Support Trust
CA	Conservation agriculture
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station
COVID-19	Coronavirus Disease 2019
CRS	Catholic Relief Services
EbA	Ecosystem-based Adaptation
EGENCO	Electricity Generation Company of Malawi
ENRM	Environment and Natural Resources Management
ESCOM	Electricity Supply Corporation of Malawi
FY	Fiscal year
GCF	Green Climate Fund
GoM	Government of Malawi
GWh	Gigawatt-hour
HPP	Hydropower plant
ITS	Interrupted time series
IUCN	International Union for Conservation in Nature
KII	Key informant interview
MCA-Malawi	Millennium Challenge Account Malawi
M&E	Monitoring and evaluation
MCC	Millennium Challenge Corporation
MEET	Malawi Environmental Endowment Trust
MERA	Malawi Energy Regulatory Authority
MMCT	Mulanje Mountain Conservation Trust
MMD	Malawi Millennium Development Trust
MOU	Memorandum of understanding
MW	Megawatt
MWh	Megawatt-hour
MWK	Malawian kwacha

NGO	Non-governmental organization
PES	Payment for ecosystem services
REFLECT	Regenerated Freirean Literacy through Empowering Community Techniques
SAP	Simplified Approval Process
SGEF	Social and Gender Enhancement Fund
SLM	Sustainable land management
SRBMP	Shire River Basin Management Program
TSP	Training Support for Partners
UNDP	United Nations Development Programme
VSL	Village Savings and Loan
WSM	Weed and sediment management

EXECUTIVE SUMMARY

A. Overview of the Malawi Compact

Malawi relies heavily on hydropower production, which generated 72 percent of its electricity in 2020 (IRENA 2021). However, changing climate, demographics, and land use practices have accelerated sedimentation and aquatic weed growth in the Shire River, along which Malawi's three primary hydropower plants (HPPs)—Nkula, Tedzani, and Kapichira—are located **(Figure ES.1).** Specifically, rapid deforestation, land use expansion, and unsustainable agricultural practices have accelerated soil erosion along the Shire River Basin, increasing sediment buildup and weed infestations that impede hydropower production.

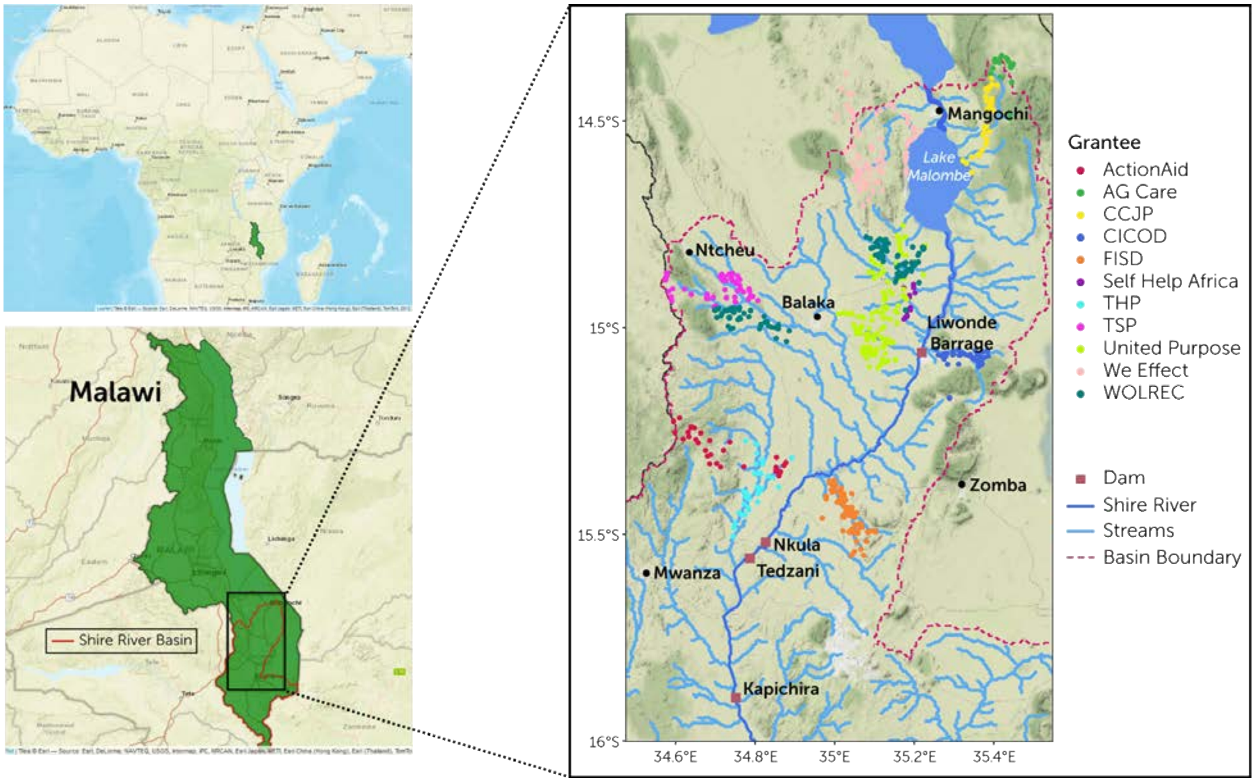
In response, the Millennium Challenge Corporation (MCC) funded the Environmental and Natural Resources Management (ENRM) Project under the Malawi Compact. The Millennium Challenge Account (MCA)–Malawi implemented the project from September 2013 through September 2018, which encompassed three activities designed to reduce costly power disruptions and increase the efficiency of hydropower generation by addressing the immediate and underlying determinants of aquatic weed growth and sedimentation in the Shire River Basin:

a. **The Weed and Sediment Management (WSM) Activity** involved procuring and using mechanical equipment to remove sedimentation and aquatic weed infestation along key points in the Shire River and was carried out in coordination with the Electricity Generation Company of Malawi (EGENCO).

b. **The ENRM Activity** supported grants to programs that reduce soil erosion by improving land management practices in high-priority catchment areas. Grant activities included producing mulch, diversifying crops, planting trees and vetiver grass, constructing box ridges and contour ridges, and developing ENRM action plans at the village level.

c. **The Social and Gender Enhancement Fund (SGEF) Activity** was implemented in tandem with the ENRM Activity. The Activity provided grants for programs in the same catchment areas as the ENRM Activity that help women and other vulnerable groups engage in more sustainable land use practices and improve their decision-making power and social outcomes. **Figure ES.1** shows the villages where the 11 ENRM and SGEF grantees focused their activities.

Figure ES.1. Map of ENRM Project locations



As part of the ENRM Activity, MCC also established an **environmental trust** to continue funding soil and land management activities and to promote gender equity, particularly around agricultural production and land management, in the Shire River Basin beyond the compact period**.**

MCC contracted with Mathematica to conduct an independent evaluation of the overall ENRM Project and the individual project activities. This report gives the final evaluation findings for the WSM Activity, environmental trust Sub-Activity, and overall ENRM Project, addressing research questions on project implementation, outcomes, and sustainability for each Activity. Our companion report (Velyvis et al. 2022) provides the final findings for the evaluations of the ENRM and SGEF activities and grant facility Sub-Activity.

Mathematica strives to improve public well-being by bringing the highest standards of quality, objectivity, and excellence to bear on the provision of information collection and analysis to our clients. This mixed-methods evaluation reflects the independent assessment of the authors who have no potential conflicts of interest, to their knowledge, in evaluating the ENRM Project. The evaluation is funded by MCC, a U.S. government agency.

B. Research questions and evaluation methods

We conducted independent performance evaluations for the WSM Activity, the environmental trust Sub-Activity, and the overall ENRM Project. For the WSM Activity and the overall ENRM Project, we conducted an impact evaluation in addition to the performance evaluations. For our performance evaluations, we collected both qualitative and quantitative data, but drew primarily from key informant interviews (KIIs) with employees from MCC, the Malawi Millennium Development Trust, and implementers; site visits; project implementation and monitoring documents; and a review of documents produced since the compact closed. Where quantitative data were available for the WSM Activity, a descriptive trends analysis was conducted alongside qualitative analysis to identify patterns in time-series data.

For WSM Activity outcomes that involved routine data collection, we carried out an impact evaluation using an interrupted time series (ITS) methodology. The ITS method estimates a pre-intervention trend from routinely collected time-series data for periods prior to the Activity in order to make predictions for subsequent periods. Those predictions are compared against observed data in the post-Activity period, with the estimated difference between the two interpreted as the Activity's impact under a set of assumptions. We apply this method to electricity and weed/sediment management outcomes using administrative data from EGENCO.

C. Implementation summary

Implementation of the **WSM Activity** experienced significant delays because of the choice to bundle the weed harvester and dredge into a single contract, contractor performance issues, and the need to conduct a re-bid procurement round. Ultimately, some pieces of equipment planned under the WSM Activity were not procured, such as the high-capacity dredger intended for the Nkula power plant. After the WSM equipment was delivered and assembled, EGENCO became responsible for carrying out all weed and sediment management activities. The new weed harvesters at Liwonde (see photo in Figure ES.2) became operational in May 2018. Although the Kapichira dredge was delivered to EGENCO in September 2018, it did not begin operating until March 2020 because of delays associated with constructing the sediment discharge pipeline, readying the disposal management placement area into which the sediment was to be discharged, and addressing equipment issues due to the dredge overheating. EGENCO staff, who were selected based on their qualifications, participated in equipment operation and maintenance trainings conducted by the equipment manufacturers. Any subsequent trainings will be conducted by EGENCO employees. Following the end of the compact, EGENCO has been unilaterally responsible for the operations and maintenance expenses of all weed management and dredging operations. Based on the most recent data available, nearly all the WSM targets have been achieved.

Figure ES.2. An operator runs one of the newly procured weed harvesters at Liwonde

As with the WSM Activity, the implementation of the **environmental trust** Sub-Activity of the ENRM Project was delayed owing to a lack of agreement between MCC and MCA-Malawi as to how to structure the trust and grant facility. By the end of the compact, fewer than half the steps identified as necessary for establishing the Shire Basin Environmental Support Trust (Shire BEST) had been completed. Since compact close, the trust has gained two permanent employees and has a full board of trustees but has not yet been able to reach the anticipated staffing levels envisioned for the current level of trust maturity.

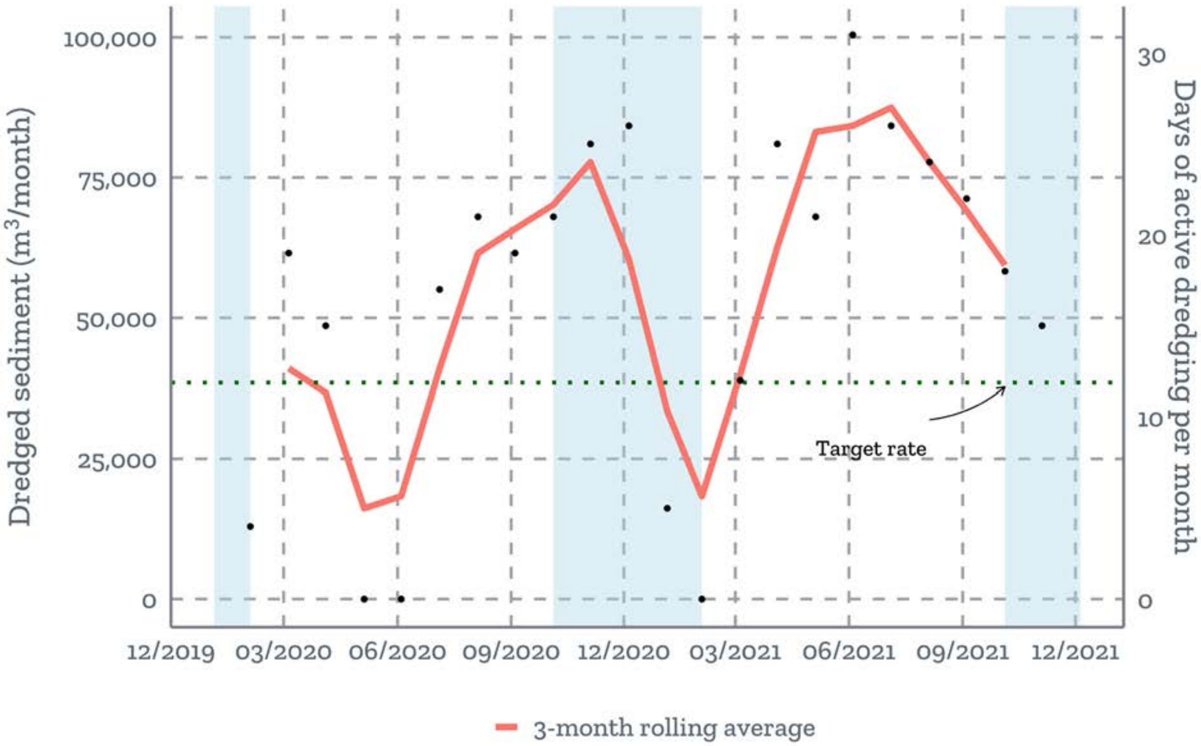
D. Summary of key findings

In this section, we summarize the key findings for the WSM Activity, environmental trust Sub-Activity, and overall ENRM Project.

1. WSM Activity

Overall, our findings show that the WSM Activity contributed to reductions in weed- and sediment-induced hydroelectric losses. Following the procurement of weed harvesters and a dredge through the Activity, the annual tonnage removed increased substantially, despite initial purchasing, procurement, and technical challenges. An average of nearly 29,000 tons of weeds per year were removed between 2019 and 2021, marking a 274 percent increase above 2012–2013 levels. The new weed harvesters enabled EGENCO to reduce the amount of weed removal downtime. About 1.17 million m^3 of sediment have been cumulatively removed from the Kapichira head pond since April 2020, which has exceeded project targets **(Figure ES.3).**

Figure ES.3. Kapichira dredge activity and sediment removal volumes per month

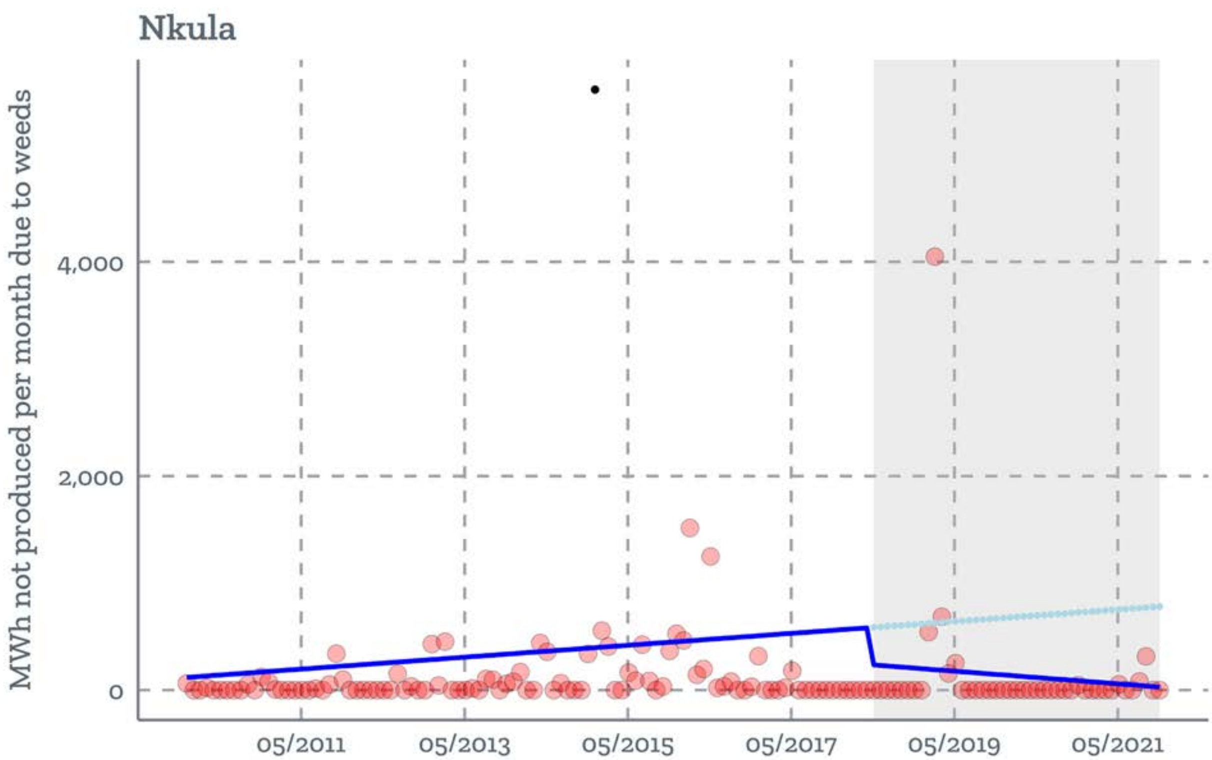


Source: Mathematica calculations using data from EGENCO.

Note: Light-blue bars denote the rainy season, which spans November through March. The target rate of 38,500 m^3/month of sediment removed is based on Fichtner (2014) estimates that would achieve an 850,000 m^3 reduction of sediment deposition in the Kapichira reservoir over four years. Monthly dredged sediment is a scale factor of the number of active dredging days, based on an assumed hourly removal rate of 270 m^3 for an average of 12 hours per day.

Across all three HPPs, electricity generation losses due to weeds and sediment were reduced following the operation of the new WSM equipment, in both the amount of electricity and the hours of plant production. The largest decline in weed-related power disruptions occurred at Nkula, where weed-related losses dropped from an average of 355 megawatt-hours (MWh) per month to 144 MWh after the compact (**Figure ES.4**). At all three HPPs, sediment-caused power losses dropped to zero MWh per month, though changes in upstream flow rates were a likely contributor. Sustaining these gains will depend on EGENCO's continued funding and carrying out of weed and sediment removal activities.

Figure ES.4. ITS results for MWh of electricity not produced per month due to weeds at Nkula power plant



Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: The gray rectangle denotes the post-treatment period, which starts in June 2018 as the first full month of operations using the MCC-funded weed-harvesting equipment. Outlier values that are two or more standard deviations from the sample mean value for that HPP are displayed in black for improved interpretability. The dark-blue line depicts the fitted results from the main ITS specification, holding contemporaneous and lagged monthly precipitation at sample mean values. All regression models include a trend term, a post indicator to denote the post-treatment period, an interaction of the trend term and the post indicator, and contemporaneous and lagged rainfall as measured at Liwonde. N = 144 monthly observations for January 2010 through December 2021.

2. Environmental trust Sub-Activity

Although the environmental trust was intended to be a sustainable financing mechanism for environmental interventions in the Shire River Basin, its inability to attract sufficient funding emerged as the central constraint on its potential impact. During implementation, discussions on funding sources for the trust focused on two options. Under a payment for ecosystem services model, downstream water users, such as utilities, water boards, industry, and irrigation users, who would benefit from sustainable land management practices would fund the trust. Another option was an endowment model under which MCC would seed the trust with a large capital injection to manage and disburse funds from. Consideration of those options consumed a good portion of the compact window, and when neither option was chosen the focus shifted to an alternative funding channel. With this alternative, the trust had anticipated that funds would become available through an environmental levy applied on utility bills, but that funding source never materialized, and stakeholders offered various explanations as for why.[1] Instead, the environmental trust received two payments from EGENCO totaling less than the $548,000 that had been specified in MOUs for 2019–2022.[2] In May 2022, Shire BEST informed us that the Illovo Sugar Company had approved 66 million MWK ($65,000) for the trust for one year to support a flood protection project in Chikwawa District. The trust awarded one grant to support catchment restoration activities but was forced to terminate the contract early and repurposed the funds to cover its own expenses. Despite these challenges, the trust has been successful in establishing a governance system with a complete board of trustees composed of integral energy and water stakeholders. Ultimately, the sustainability of Shire BEST and its capacity to expand improved soil and land management practices throughout the Shire River Basin rests on its ability to secure funding at the scale envisioned during the compact: between $700,000 and $1.5 million per year.

3. Overall ENRM Project

Findings from our evaluation show that, overall, the ENRM Project contributed to increases in the efficiency and reliability of the three Shire River HPPs through reductions in weed infestations and sediment buildup. We describe these outcomes below.

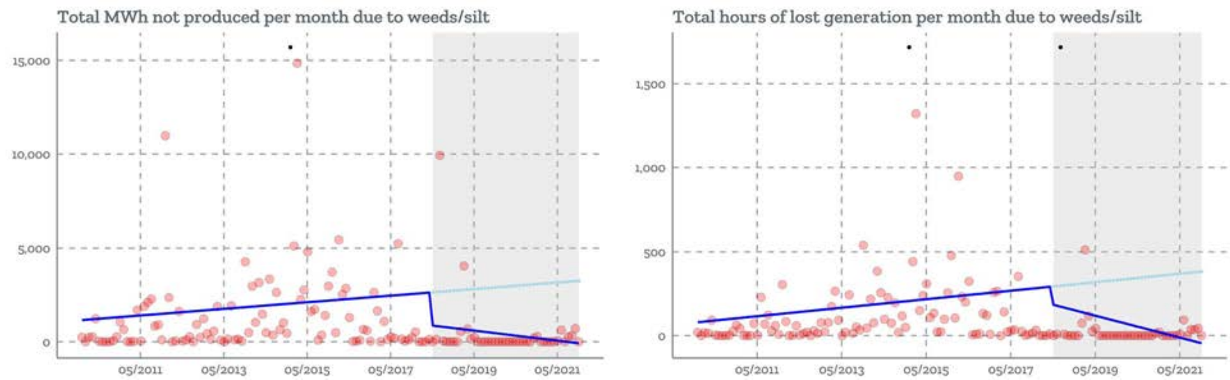
- ENRM Project activities led to significant reductions in weed- and sediment-related electricity losses, both in terms of output and total hours of production **(Figure ES.5).** Notably, the month-to-month performance variability of the three Shire River hydropower plants decreased in the post-treatment period, which suggests an increase in reliability of electricity supply. However, as these improvements were observed even before the Project activities, other factors, such as investments made by the World Bank's Shire River Basin Management Program, were probably at least partly responsible.[3]

[1] While the levy itself was not approved by the Malawi Energy Regulatory Authority (MERA), the tariff applications submitted by EGENCO and Electricity Supply Company of Malawi (ESCOM), the state-owned power transmission and distribution company, included a levy value and were approved, albeit lower than the requested tariff. For example, ESCOM requested a 60 percent increase in the average tariff over the base year rate (ESCOM 2018), whereas MERA approved a 31 percent increase (USAID 2019). It is conceivable that funds requested by ESCOM and EGENCO for Shire BEST were directed to their own use instead.

[2] As per correspondence with Shire BEST in May 2022, EGENCO had not disbursed 165 million MWK that had been part of the two MOUs.

[3] At its closure, the World Bank's Shire River Basin Management Program spent a total of US$121.9 million between 2012 and 2019 on three components: Shire Basin planning (US$42.1 million), catchment management (US$26.1 million), and water-related infrastructure (US$52.9 million).

Figure ES.5. ITS results for hydroelectricity losses per month due to weeds or silt combined across Nkula, Tedzani, and Kapichira

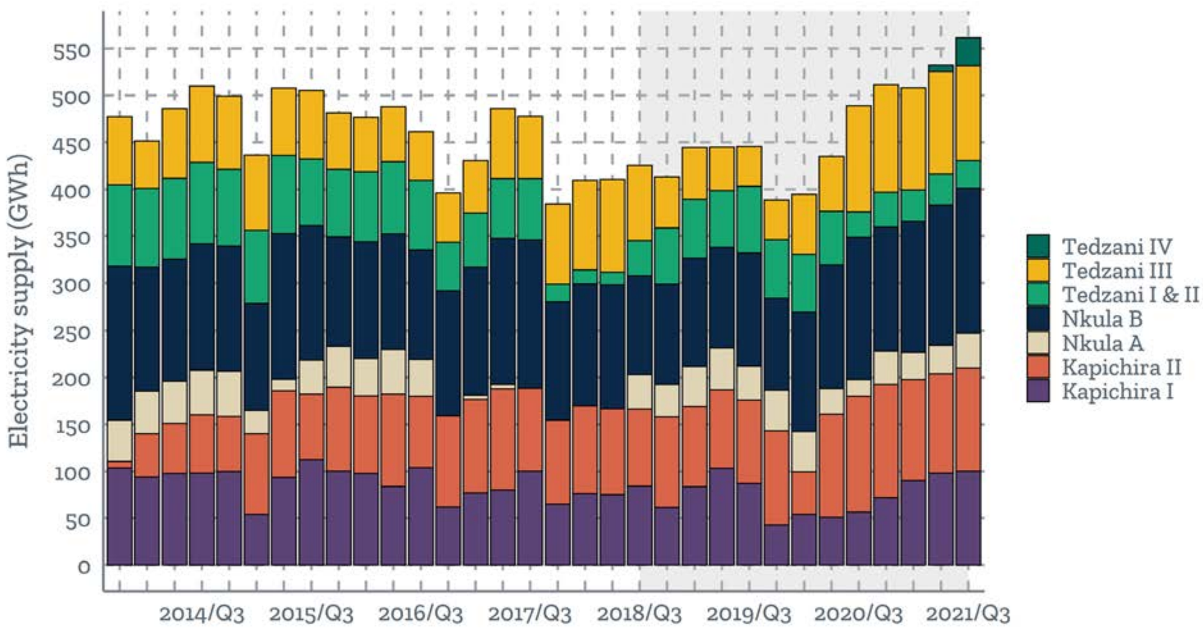


Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: The gray rectangle represents the treatment period, which we identify as beginning when the Liwonde weed-harvesting equipment was operational in May 2018. The light-blue dotted line projects the pre-treatment trend into the post-treatment period and represents the "no project" counterfactual. Observed values that are 2.5 standard deviations or more away from the sample mean are top-coded at that value for display purposes (in black), but their actual values are used in all regression models. The regression coefficients from the primary specification ITS model are displayed in Table VI.2. N = 144 monthly observations for January 2010 through December 2021.

- Electricity reliability has also improved following the start of WSM equipment operations, measured as reductions in the duration and frequency of turbine faults in each of the three HPPs.
- Across the three HPPs, availability levels between 2020 and 2021 exceeded 90 percent and 95 percent, surpassing the end-of-compact target of 89 percent. However, these levels were not markedly different from those recorded in 2015 and 2016 before the new WSM equipment became available.
- The three hydropower plants generated the most electricity per quarter at the end of the evaluation period, averaging 519 GWh/quarter in the year spanning 2020/Q4 to 2021/Q3 **(Figure ES.6).** However, this peak exceeds earlier production levels by only small percentages and fell short of achieving the compact target of 677 GWh/quarter.

Figure ES.6. Quarterly electricity supply by HPP station (GWh)



Source: Mathematica calculations using data from EGENCO and MCC.

Note: The gray rectangle denotes the post-treatment period that starts in 2018/Q3 as the first full quarter operating any MCC-funded WSM equipment. Monthly data from July 2017 to September 2021 were summed by quarter to match the cadence available in MCC's closeout ITT. N = 32 quarterly observations for 2013/Q4 through 2021/Q3.

Stakeholders noted that the sustainability of these gains rests on continued performance and financing from EGENCO, as its weed and sediment activities were seen as the key contributor to these outcomes. Stakeholders also acknowledged the need for consistent promotion and adoption of SLM practices alongside weed and sediment management activities, which can be realized if Shire BEST is able to secure long-term funding. Despite improvements in hydropower plant efficiency and reliability, this evaluation was unable to provide evidence that these positive outcomes had led to poverty reduction and equitable economic growth. Findings from our comparative case analysis (Velyvis et al. 2022) revealed that households who participated in ENRM and SGEF activities reported higher incomes, improved agricultural production, and increased alternative-income generating opportunities; even so, these gains could not be linked solely to the ENRM Project, as we did not collect systematic data on all participant revenue streams or comparative outcomes for nonparticipants.

E. Conclusion

Less than 20 percent of Malawians have access to electricity and the economic, social, and environmental benefits conferred by electricity relative to traditional fuels. While building new electricity generation assets using hydropower or solar energy is one way to increase access, improving the operational performance of existing HPPs by removing obstacles to achieving maximum generational potential is still another. Moreover, Malawi's dependence on hydropower reveals that the health of an energy sector is not determined solely by its generation assets or transmission and distribution infrastructure, but also by the environmental conditions in which HPPs are situated.

The ENRM Project sought to improve HPP performance and overall electricity supply through two channels. The first was to provide new equipment to increase active storage capacity and resolve the weed infestation and sediment deposition problems that had been accumulating prior to the compact's investments. The second addressed the root causes of weed and sediment accumulation by funding programs to encourage SLM adoption throughout the Shire River Basin, with the intent of reducing erosion and nutrient runoff. Success through this second channel would help alleviate, but not eliminate, the need for the first. While some degree of erosion and runoff will continue to be inevitable, the Project intended that a new equilibrium emerge in which preventive SLM measures would become the primary means of stemming weed and sediment growth. At the same time, the WSM Activity equipment will continue to operate in a maintenance mode, such as how operations at Kapichira will transition from a capital dredging to a maintenance dredging strategy once the active storage capacity target has been achieved.

Our evaluation finds that electricity supply both increased and improved as a result of the WSM Activity by reducing generation losses caused by weed and sediment buildup. We did not find any evidence that the environmental trust's activities were key contributors to those loss reductions, because Shire BEST has not yet achieved the operational scale to advance sustainable soil and land management practices throughout the Shire River Basin. While the WSM Activity and the environmental trust were designed around a relatively unique problem specific to the Malawian context, of limited electricity supply and underperforming HPPs, future investments that have analogous aims could benefit from evaluations that examine inter-donor collaboration, transitioning management over activities whose implementation is delayed, and the trade-offs between establishing new and rehabilitating existing institutions.

I. INTRODUCTION

In 2011, the Millennium Challenge Corporation (MCC) partnered with the Government of Malawi (GoM) to fund the first compact in the country—a $344.8 million energy sector compact to reduce poverty in Malawi through equitable and sustainable growth (MCC 2013).[4] The compact's design was informed by a 2008 analysis conducted by the GoM and the Millennium Challenge Account-Malawi (MCA-Malawi) that identified a lack of consistent, reliable, and affordable electricity as a key constraint to Malawi's economic growth (Republic of Malawi and MCA-Malawi 2008). Political violence in Malawi prompted MCC to place a hold on compact assistance in July 2011 and to formally suspend the compact in March 2012. After the GoM passed several reforms and commitments to public accountability, MCC reinstated the compact in June 2012, and the compact was implemented by MCA-Malawi from September 2013 to September 2018.

The compact consisted of three distinct but complementary projects: (1) the Infrastructure Development Project, focused on rehabilitating and modernizing Malawi's power system ($255.4 million); (2) the Power Sector Reform Project, which undertook institutional and regulatory reform to improve the regulatory framework and energy policy environment ($27.4 million); and (3) the Environmental and Natural Resources Management (ENRM) Project, which worked to reduce costly disruptions and increase the efficiency of hydropower generation by mitigating aquatic weed growth and sedimentation in the Shire River Basin ($19.9 million) (MCC 2020).[5]

MCC contracted Mathematica to conduct an independent evaluation of the overall ENRM Project as well as the individual project activities. In this report, we provide final findings of the ENRM Project evaluation and two project activities, addressing research questions on implementation, outcomes, and sustainability. We used a tailored, rigorous mixed-methods framework for each activity's evaluation, drawing from several data sources, including key informant interviews (KIIs), and a review of documents produced by stakeholders. Our findings have implications for weed and sediment management interventions designed specifically for reducing hydroelectricity losses, both in Malawi and in other contexts, with resulting lessons learned on implementation and behavioral change that will be valuable for policymakers, donors, practitioners, and other stakeholders. In the rest of this chapter, we describe the ENRM Project, briefly explain the project's theory of change and logic model, and summarize key implementation details.

A. Overview of the ENRM Project

Hydroelectricity powers Malawi's economy and was the energy source for 72 percent of the country's generated electricity in 2020. [6] Three hydroelectric power plants (HPPs)—Nkula, Tedzani, and Kapichira—produce the majority of Malawi's hydroelectric power and are all located on the Shire River

[4] This value is the final disbursed amount.

[5] These values are final disbursed amounts.

[6] The installed capacity at the Nkula, Tedzani, and Kapichira hydropower plants are 135.1 megawatts (MW), 121.1 MW, and 129.6 MW, respectively (EGENCO 2022). The only other hydropower plant that is currently operational in the country is the Wovwe power station (4.5 MW), located on the Wovwe River in Karonga district. Two other large hydropower plants in Malawi are in the planning stage. The Songwe hydropower plant, to be jointly owned with Tanzania, will be located in the Mbeya district on the Songwe River, with an expected capacity of 180 MW (90 MW will be available to Malawi). The Mpatamanga hydropower plant with a planned capacity of 258 MW will be located in the Blantyre district on the Shire River; it will be downstream of Nkula and Tedzani but upstream of the Kapichira hydropower plant.

and operated by the Electricity Generation Company Malawi Limited (EGENCO), a parastatal energy generation company. These plants, also referred to as the "cascade," have a combined nameplate capacity of 386 megawatts (MW), representing 70 percent of the country's total generation capacity (IRENA 2021).

However, excessive sedimentation and aquatic weed growth in the Shire River have contributed to substantial disruptions in electricity generation by these plants, forcing shutdowns for repairs and maintenance and ultimately reducing electricity supply and reliability. To overcome these electricity losses, the ENRM Project focused on addressing overabundant sedimentation and weeds in the Shire River Basin, and the land practices that exacerbated the overgrowth. The ENRM Project included three main activities: (1) the Weed and Sediment Management Activity (WSM; $15.9 million) to remove weeds and sediments upstream of the HPPs, (2) the ENRM Activity ($10 million) to address unsustainable land management practices that contribute to soil runoff, and (3) the Social and Gender Enhancement Fund (SGEF) Activity ($2 million) to tackle underlying socioeconomic causes of unsustainable land management practices. As part of the ENRM Activity, the project sought to establish an environmental trust to continue funding sustainable land management (SLM) and social and gender programs in the Shire River Basin beyond the period of direct assistance from MCC and MCA-Malawi.

B. Project logic and theory of change

The ENRM Project aimed to reduce excessive sedimentation and weed infestation in the Shire River Basin to reduce disruptions in the generation of hydroelectricity at the three HPPs. Through the following pathways, these WSM, ENRM, and SGEF Activities were hypothesized to improve the reliability of the Shire River hydropower plants. The core program logic was as follows:

a. If weeds and sediment in the Shire River are removed, then hydroelectric turbines would experience fewer and less severe episodes of clogging. Sediment removal would have the additional effect of increasing reservoir storage levels and reducing hydroelectric losses because of insufficient water flow rates.

b. Effective weed and sediment management would enable electricity generation plants to operate closer to their capacity levels.

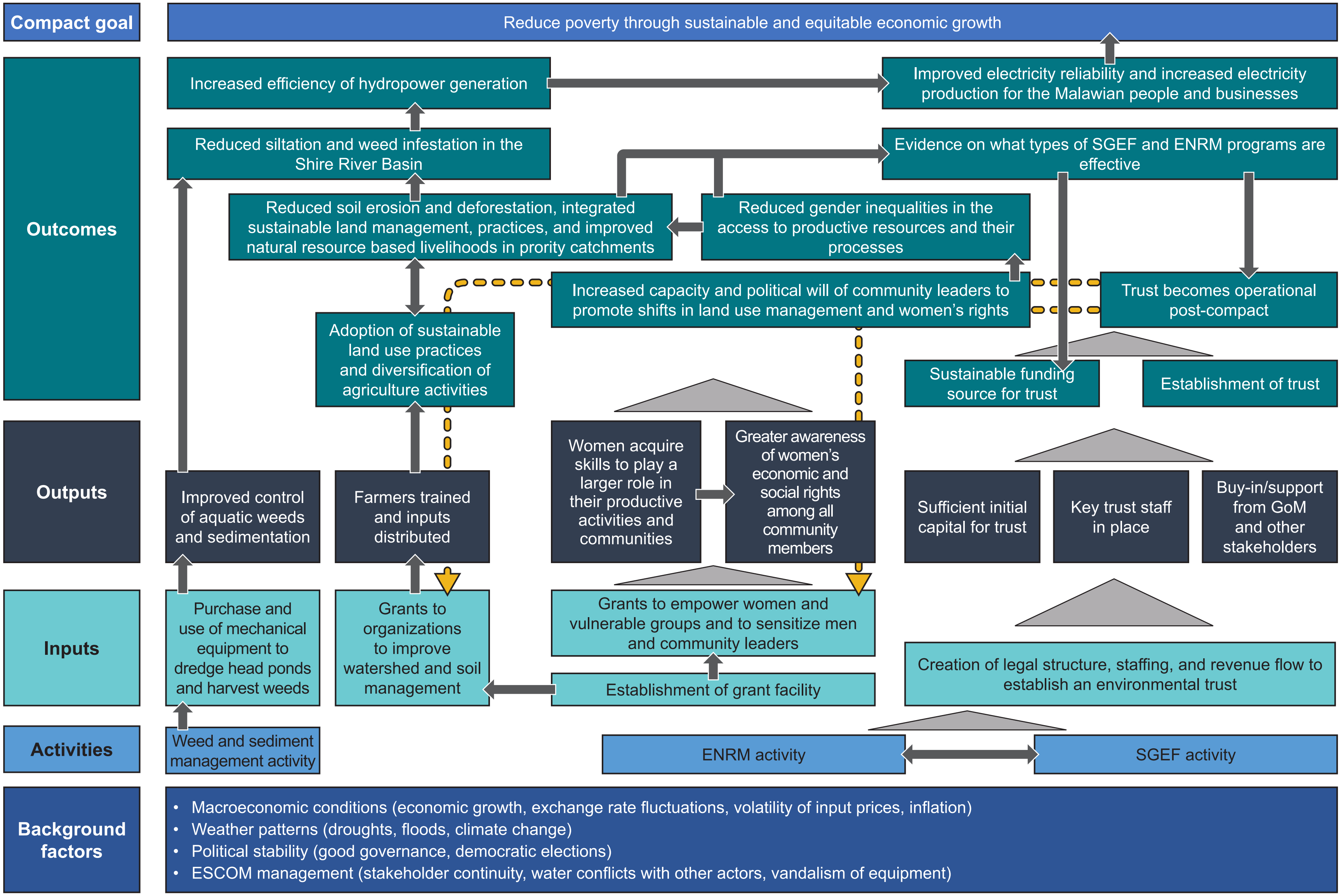
c. If community interventions are implemented, then households and communities will be better equipped to improve land use and watershed management practices, thus decreasing siltation and erosion in the project area. Communities would be incentivized to adopt improved land management practices because doing so would plausibly increase crop yields over the long run by reducing losses of soil, moisture, and soil fertility.

d. If an environmental trust is set up, then further initiatives and organizations can be funded, thereby leading to the sustained improvement of land use practices that would provide continued support for more efficient hydropower generation (MCA-Malawi 2014a).

The ENRM Project logic is captured in detail in Figure I.1, illustrating how the compact goal of poverty reduction through "sustainable and equitable economic growth" would be achieved through the WSM, ENRM, and SGEF Activities. Key inputs include the acquisition of mechanical equipment for the WSM Activity, the distribution of grants to support implementers to improve watershed and soil management for the ENRM and SGEF Activities, and the creation of new environmental institutions for the ENRM Sub-Activities. Inputs are linked to outputs that demonstrate that project activities have been executed. Outputs link to multiple tiers of outcomes that the ENRM Project was designed to affect. The bottommost set of outcomes are the most immediately achievable. They are also preconditions for achieving both intermediate outcomes, such as reduced siltation and weed infestation, and a larger evidence base of effective SGEF and ENRM programs, and the ultimate outcomes of increasing hydropower generation efficiency and improving electricity supply and reliability.

The theory of change also reflects the potentially bidirectional relationship between certain outputs and outcomes denoted by double-headed arrows. Yellow dotted lines indicate the inputs the environmental trust is intended to fund after the compact ends. Successful ENRM grant programs may lead to increased adoption of SLM practices as farmers experience and witness the benefits of such practices, thereby creating a positive feedback loop. Furthermore, the logic model also recognizes that ENRM and SGEF grantee program effectiveness can be used by the trust as evidence for fundraising efforts in its operations.

Figure I.1. Program logic for the ENRM Project



C. Description of project activities

Below, we briefly describe the intended aims of each of the three ENRM Project Activities. Table I.1 summarizes the timeline for these activities and Mathematica's evaluation.

Table I.1. ENRM Project timeline

Calendar year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Overall Compact														
MCC and Government of Malawi enter into compact	■													
Compact takes effect			■											
Compact terminates								■						
WSM Activity														
WSM Activity design				■	■	■								
WSM equipment procurement						■	■	▨	■	■				
WSM Activity training and implementation								▨	■	■				
ENRM and SGEF grant activity														
Grant facility design				■	■									
Proposal review and selection					■									
ENRM and SGEF grant implementation					■	■	■	■						
Environmental trust														
Trust planning and design					■	■	■	■						
Trust operationalization and start-up									■	■	■			
Trust stabilization and expansion												■	■	■
Mathematica evaluation														
Evaluability assessment and evaluation design						■	■							
Interim data collection, analysis, and report								■	■					
Final data collection, analysis, and report										▨	■	■		

■ Actual ▨ Anticipated completion

The **WSM Activity** sought to tackle the immediate issue of excessive sedimentation in the head ponds of power plants and excessive weeds in the Shire River upstream. Under this Activity, MCA-Malawi purchased various pieces of equipment to be operated and maintained by EGENCO. At the Kamuzu barrage in Liwonde, weed harvesters, tipper trucks, and a conveyor belt were purchased to improve EGENCO's capacity to collect and remove aquatic weeds, notably water hyacinths and uprooted elephant grass, upstream of all their hydroelectric power plant generation assets. At the Kapichira site, a high-capacity diesel-powered dredge was procured along with backhoes and tipper trucks to aid in removing accumulated sediment in that plant's head pond.

Figure I.2 illustrates the locations of the barrage and the Kapichira plant along the Shire River. When the compact ended, EGENCO had agreed to maintain all purchased equipment and ensure that staff were trained to use the equipment properly. Through these components, the activity aimed to increase total electricity supply, reduce blackouts and brownouts, and ultimately improve electricity reliability for grid-connected households and businesses.

The **ENRM Activity** targeted unsustainable land management practices in the Shire River Basin that cause increased sediment runoff and weed growth. These practices included rapid deforestation and agricultural expansion into ecologically sensitive areas, such as along riverbanks and on sloped locations with high erosion risks. Grant activities included mulch production, crop diversification, planting of trees and vetiver grass, construction of box ridges and contour ridges, and development of village-level ENRM action plans. Through the introduction of SLM practices, these activities aimed to reduce sediment runoff while improving crop yields. The Activity supported grants to programs designed to improve land management practices in high-priority catchment areas. These "hot spot" areas were identified in baseline assessment reports as large contributors to excessive soil runoff in the Shire River (LTS International et al. 2010, 2011, 2013, 2014a, 2014b, 2014c).

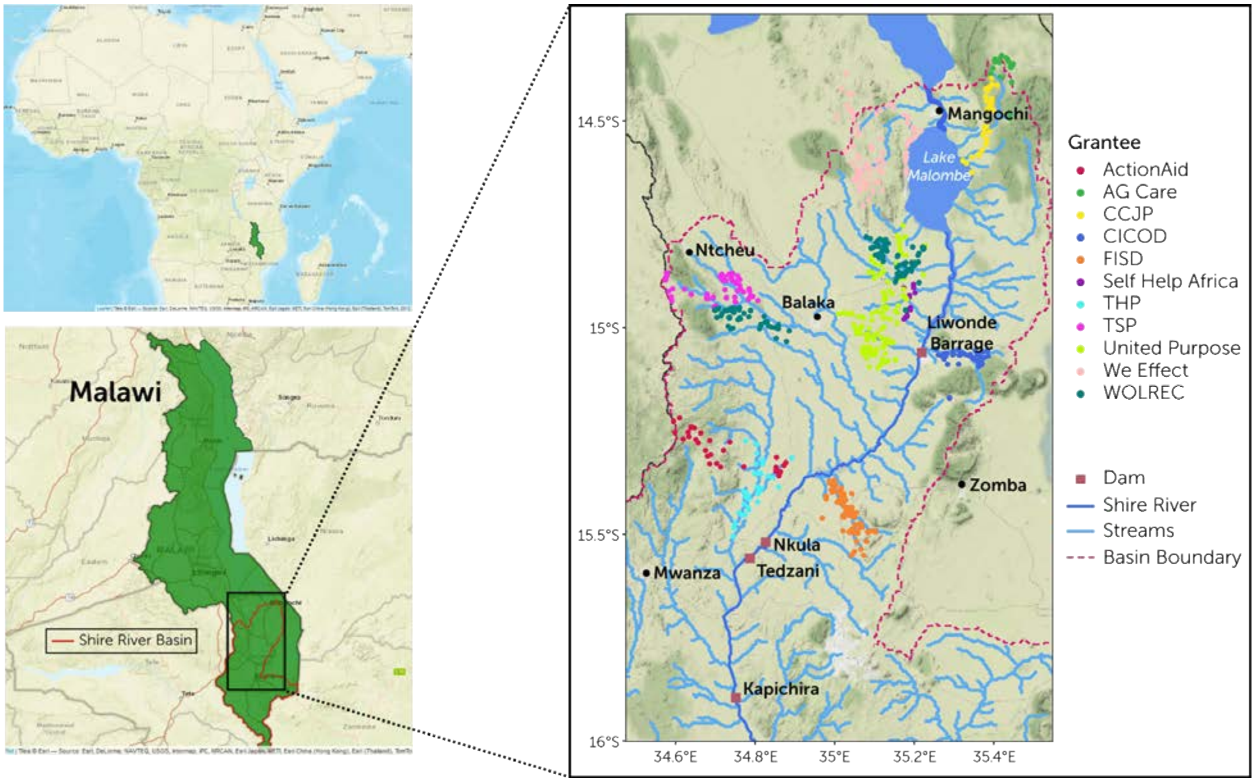
The **SGEF Activity** aimed to address fundamental socioeconomic causes of unsustainable land management and was implemented in tandem with the ENRM Activity. The SGEF Activity provided grants for programs in the same catchment areas as the ENRM Activity, but targeted women and vulnerable populations in activities focused on SLM practices as well as improved decision-making power and improved social and economic outcomes. Men who have limited control of resources in a matrilineal society were likewise targeted, as the broader activity objective was to strengthen inclusive household and community decision making. Specific activities included conducting business skills, leadership, and gender equity trainings; organizing community REFLECT Circles that often included a literacy development and numeracy component; and forming Village Savings and Loan (VSL) groups and environmental management or forestry groups.[7] To support facilitators in integrating discussions around gender equity and SLM practices into REFLECT Circles, MCA-Malawi developed technical assistance manuals in Chichewa and English. Additionally, the grant programs worked with communities to develop alternative economic opportunities in place of charcoal production, which contributes to deforestation.

Two Sub-Activities of the ENRM Activity were meant to serve as financing mechanisms: the grant facility and the environmental trust. MCA-Malawi established a **grant facility** that identified the most promising intervention approaches through a competitive application process to fund the ENRM and SGEF Activities. Of the 57 grant applications that MCA-Malawi received, 11 three-year grants were chosen, covering four of the five high-priority catchment areas in the Middle Shire and four of the seven high-priority catchment areas in the Upper Shire. Grants were implemented from 2015 to 2018. Through its application process design, the grant facility encouraged grantees to implement activities that addressed both ENRM and SGEF objectives. However, some grantees focused more extensively on particular objectives. The grantees conducted activities in 771 villages, with each grantee operating in 20 to 127 villages. A map of the villages in which grant facilities conducted their activities is shown in Figure I.2. More information on the grant-implementing organizations and their activities can be found in our interim report (Coen et al. 2019).

With the support of MCC, MCA-Malawi supported the establishment of an **environmental trust** as a Sub-Activity of the ENRM Activity. This trust was intended to ensure continued funding for land management and gender equity-promoting activities in the Shire River Basin after the compact ended, by providing financial support to implementers whose activities would contribute to sustainable soil and land management. Although MCA-Malawi helped establish it, the trust—known as the Shire Basin Environment Support Trust (Shire BEST)— was created as an independent, private entity that would be responsible for developing a sustainable financing model.

[7] REFLECT (Regenerated Freirean Literacy through Empowering Community Techniques) Circles aimed to bring community members together to discuss issues the participants identified as important, ensuring that people's voices could be heard equally and that participants continually analyzed dynamics of power within their communities (ActionAid 2017; REFLECT 2009).

Figure I.2. Map of ENRM Project locations



D. Implementation summary

MCA-Malawi oversaw the implementation of the whole Project, with each Activity being implemented by different groups of stakeholders. In this section, we summarize implementation of each Activity we evaluated. A more in-depth description of project implementation can be found in our interim report (Coen et al. 2019).

The WSM Activity implementation experienced significant delays because of the choice to bundle the weed harvester and dredge in a single contract, contractor performance issues, the eventual cancelation of the Nkula dredger procurement, and the need to conduct a re-bid procurement round. Although the weed harvesting equipment was delivered and operational before the compact ended (in May 2018), procurement and technical delays meant that the dredging activity did not actually begin until later. EGENCO and MCA-Malawi's follow-on agency—the Malawi Millennium Development Trust (MMD)—stepped in to advance the dredging activity after the compact closed. The dredge arrived in Malawi in late September 2018. EGENCO worked with the manufacturer, Ellicott Dredges, in its assembly and launch, which took place through November 2018. Dredging did not begin for another year and a half because the sediment discharge pipeline was yet to be constructed (finished in September 2019), the disposal management placement area only became ready in January 2020, and equipment challenges associated with dredge overheating required the installation of an engine expansion tank which occurred in February 2020. Active dredging began in March 2020 and was fully operational the following month. Ultimately, some pieces of equipment planned under the WSM Activity were not procured, such as the high-capacity dredger intended for the Nkula power plant. After the WSM equipment was delivered and assembled, EGENCO assumed responsibility for all weed and sediment management activities.[8] EGENCO staff, who were selected based on their qualifications, participated in equipment operation and maintenance trainings conducted by the equipment manufacturers (Aquarius-Systems in the case of the weed harvester and Ellicott for the dredge). Any subsequent trainings will be conducted by EGENCO employees. Following the end of the compact, EGENCO has been unilaterally responsible for the operations and maintenance expenses of all weed management and dredging operations. Nearly all the WSM targets have been achieved, based on the most recent data available, as shown in Figure I.3. Total plant availability across Nkula, Tedzani, and Kapichira exceeded the end-of-compact target of 90 percent. The amount of electricity not produced because of weeds or sediment (a total of 541 megawatt-hours [MWh] for July 2020 through June 2021) was dramatically lower than the target of 4,640 MWh. One target not achieved was electricity generation losses at Tedzani, where weed-related disruptions resulted in 441 MWh of electricity not generated. While there were no targets for weed management unit costs or total spending, EGENCO is spending more on this activity than at baseline, and doing so more efficiently, saving $12 per ton of weed harvested relative to costs during the 2012–2013 baseline period.

[8] The original plan was for the Electricity Supply Corporation of Malawi Limited (ESCOM) to be involved in WSM activities, but following the split between ESCOM and EGENCO effective in January 2017 as part of a restructuring of the country's power market, with EGENCO tasked with electricity generation assets and ESCOM with electricity transmission and distribution, these activities naturally were assigned to EGENCO.

Figure I.3. Post-compact performance for key ENRM Project indicators

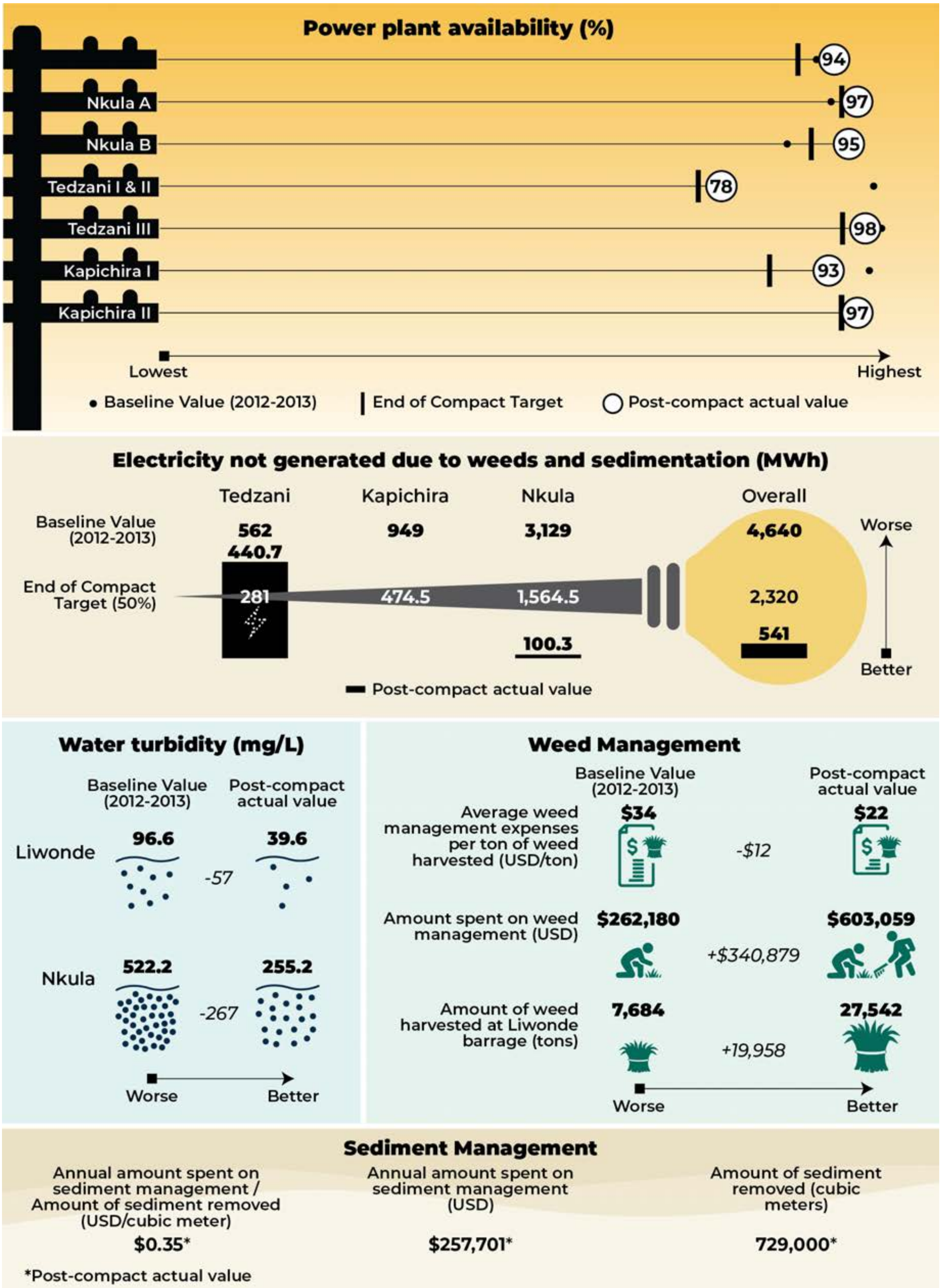


Figure I.3. ***(continued)***

Source: Mathematica calculations based on data from MCC and EGENCO.

Note: Power plant availability values are from the latest EGENCO data and are average values for October 2020 to September 2021. Electricity not generated values are from EGENCO and water quality data for Liwonde and Nkula/Walkers Ferry are from Blantyre and Southern Region Water Boards and are average values from July 2020 to June 2021. Water turbidity data for Nkula are measured from Walkers Ferry. Weed management expenses and average amount spent on weed management are estimated based on costs for Q1 and Q2 2020. The weed harvested at Liwonde Barrage value is from the latest EGENCO data and reflects annual totals from July 2020 through June 2021. The amount of sediment removed is from the latest EGENCO data and reflects annual totals from January 2021 to December 2021. Sediment management expenses are from the latest MCC indicator tracking table (ITT) and are annual totals over all available quarters for calendar year 2020. For outcomes with no end-of-compact target, the "Actual – Target" value represents the difference between the latest actual values and the baseline 2012–2013 values. USD values were calculated from the 771.55 Malawian Kwacha (MWK) to 1 USD exchange rate on January 15, 2021 (based on https://www.xe.com/currencytables/?from=MWK&date=2021-01-15#table-section).

The **ENRM and SGEF Activities** were implemented in tandem, with the grants they made overseen by the **grant facility**. MCA-Malawi managed the grant facility and worked with 11 grantee organizations that were selected to carry out the ENRM and SGEF programming through a competitive application process, which received 57 applications (a full list of selected grantees can be found in Velyvis et al. 2019). A total of $6 million was disbursed to support the grantees' projects and 74,000 people directly benefited from these programs (MCC 2020). The grant facility did not define how participant targeting and recruitment should be conducted. Most of the villages selected by grantees were located in or near "hot spots" as suggested by the Middle and Upper Shire Baseline Assessments and Action Plan (LTS International et al. 2010, 2011, 2013, 2014), indicating that grantees were successful in targeting their programming in the areas of highest priority for catchment restoration activities. Within those villages, male and female participants were selected based on whether they were actively engaged in agriculture. For the SGEF behavior change and sensitization activities, grantees also targeted traditional male leaders for participation, knowing that shifting community norms is more effective when community leaders are on board. Women were the majority of participants in both the program and the leadership training. The majority of monitoring indicators, including the number of planted trees that survived, the number of women completing leadership training, and the number of operational REFLECT circles, exceeded their compact closeout targets.

The implementation of the **environmental trust** sub-activity of the ENRM Project was delayed due to a lack of agreement between MCC and MCA-Malawi as to how to structure the trust and grant facility. An initial procurement round for selecting an implementing organization failed. Because the round occurred during August when many European organizations were on leave, only one bid was received, from the Malawi Environmental Endowment Trust (MEET). Since MCC and MCA-Malawi understood there was broader interest by organizations to submit bids, they canceled the procurement round. Under a re-procurement, a consortium with the requisite combined expertise to establish the trust, formed by MCC and MCA-Malawi's direct efforts, was awarded a cooperative agreement. That cooperative agreement with Mulanje Mountain Conservation Trust (MMCT), International Union for Conservation of Nature (IUCN), Wildlife Conservation Society, and MEET was canceled with only one year left before the compact close because of incompetent program delivery and in response to fraud and embezzlement allegations. By the end of the compact, fewer than half the steps needed for establishing the Shire Basin Environmental Support Trust (Shire BEST) had been completed. Since compact close, the trust has gained two permanent employees and has a full board of trustees but has not yet been able to reach the anticipated staffing levels envisioned for the current level of trust maturity. Chapter V provides additional details about developments in the implementation of the trust since the end of the compact. Implementing partners are the key participants for this component of the ENRM Project and are selected through a competitive application process open to organizations involved in catchment restoration work in the Shire River Basin. Shire BEST has awarded a single contract to an implementing partner because the organization has yet to secure stable funding at the level of $700,000 to $1.6 million annually, which would cover both trust administration and operating costs (Spergel 2015).

II. LITERATURE REVIEW

This chapter updates the literature review in our interim findings report (Coen et al., 2019) with recently published evidence on two topics central to the ENRM Project: (1) interventions designed to improve the productivity of HPPs in settings where land degradation affects electricity production, and (2) the establishment of environmental trusts. Specifically, this review provides context for interpreting the ENRM evaluation and our final findings by summarizing recent literature on the different interventions implemented by the WSM Activity and Environmental Trust Sub-Activity stakeholders. An updated literature review of recent evidence on programs implemented by the ENRM and SGEF Activities is in our companion report (Velyvis et al., 2022). At the end of each section, we highlight gaps in the literature and explain how the policy-relevant evidence of the ENRM Project evaluation helps to fill the gaps.

A. Effectiveness of strategies to mitigate land degradation's impact on hydroelectric production

Hydropower is a critical resource in sub-Saharan Africa—particularly in Malawi, where 72 percent of electricity comes from (International Renewable Energy Agency [IRENA], 2021). There are several threats to the stability of hydroelectricity, however, including excessive siltation and aquatic weed infestations that can lower hydropower plants' output and force shutdowns. In 2014, for example, sedimentation in the head pond of the Nkula hydropower plant reduced active storage capacity, resulting in almost a 70 percent loss of capacity (LTS International, 2014a). Aside from reducing reservoir capacity, sediment flows from erosion can damage turbines and other hydropower plant equipment (Basson, 2004; Schellenberg et al., 2017). Infestations of aquatic weeds, such as water hyacinth and elephant grass, also diminish hydropower plant productivity by clogging turbines, and can adversely affect ecosystems by slowing river flow (Mellhorn, 2014). Given the scant access to electricity in rural areas (with only 4 percent connected to the electric grid) and the unmet demand (365MW of supply compared with an estimated demand of 440MW), these disruptions are expensive (World Bank, 2018; World Bank, 2019).

Several active measures can mitigate the effects of sediment and weed accumulation on hydropower productivity. Dredging can remove sediment and increase reservoir storage, but it is generally seen as a last resort because of its expense and often must be done continuously if the underlying causes of sedimentation are not also addressed (Amasi et al., 2021). Strategies to prevent and control soil erosion are effective and less expensive alternatives (Adeogun et al., 2016; Kondolf et al., 2014). Various cross-slope barrier soil and water conservation techniques also reduce runoff and soil loss in sub-Saharan Africa (Wolka et al., 2018). There is evidence that biological control has more potential than mechanical and chemical interventions for addressing weed infestation (Phiri et al., 2001). For effective control of larger weed outbreaks, however, concurrent application of all three methods may be necessary.

Through this evaluation, we provide evidence of the effects of mechanical interventions on weed and sediment management and their ensuing impact on hydropower generation along the Shire River. Because EGENCO collects data on hydropower losses by cause (such as weeds or silt), we can provide quantitative evidence on how effectively the intervention reduces the amount of downtime and lost electricity production, and how it affects operating costs on a per-plant and per-intervention basis. Because the scale of the ENRM and SGEF grantees' activities was unlikely to be large enough to influence weed and sedimentation patterns, it is likely our approach is exclusively capturing the impacts of the WSM interventions. Consequently, this evaluation contributes to the literature by quantifying the electricity losses that have been avoided because of the investments in weed and sediment removal.

B. Environmental trusts as vehicles for environmental goals

Sustainable financing is integral to environmental and natural resource management. Environmental trust funds, defined as independent grant-making bodies that mobilize, blend, and manage financial flows for environmental impacts (UNDP, 2016), have been commonly adopted throughout sub-Saharan Africa. Literature has revealed how environmental trust funds can be effective long-term, stable financing tools for selected environmental objectives by serving as vehicles to catalyze and diversify green investments to groups, regions, and sectors that may otherwise not receive funds (Moye, 2002; UNDP, 2016).

Environmental trusts can have positive impacts on environmental preservation, biodiversity, climate change mitigation, and adaptation (UNDP, 2016). An assessment of the Global Conservation Fund found significant impacts on deforestation rates in and around protected areas, with higher management effectiveness scores correlating with lower deforestation rates (Bonham et al., 2014). In addition, by expanding the financing focus from biodiversity to encompass livelihood improvement and sustainable development in communities surrounding protected areas, conservation trusts can further support environmental goals by mitigating human-induced environmental threats (Spergel & Taïeb, 2008). Environmental trust funds can have a broader impact on country-level environmental policies, as shown in the assessment of the Trust Fund for Environmentally and Socially Sustainable Development, which financed policy analyses and capacity building to inform national policies (The World Bank, 2017).

In our interim report (Coen et al., 2019), we discussed the operational drivers of successful environmental trust funds: strong feasibility studies; diversified financing; strategic and financial planning; strategic partnerships; political support; financial expertise; and strong reporting, monitoring, and evaluation (Bladon et al., 2014; Ostrom, 1999; Snowdon, 2004). Researchers have also suggested the success of environmental trusts is driven by alignment with national priorities (Halimanjaya et al., 2014); stakeholder agreement on the risks and mitigation responsibilities (Dear et al., 2016); and flexibility in design, structure, and operations to address challenges (Chléirigh, 2015). Findings from Süring et al. (2021) likewise reveal the importance of strategic partnerships—specifically with private-sector actors—but underscore the challenges of establishing and maintaining these partnerships in the face of administrative, financial, and political constraints.

The potential of environmental trusts to achieve environmental goals is largely dependent on facilitators of their establishment and continued operation. Our evaluation shares important insights on the pitfalls and challenges in the establishment and scaling up of new, independent conservation institutions. This evaluation can only provide a minimally substantive contribution to the literature about the impacts of environmental trusts, however, given the limited grant-making Shire BEST has engaged in. Only if Shire BEST is able to scale and command a budget capable of funding conservation programs throughout the Shire River Basin will some of the impacts of those activities on weed and sediment reduction be detectable. Until then, our findings highlight the difficulties in crafting new institutions, even those with mandates that are broadly accepted across the span of important private, public, and nongovernmental stakeholders.

III. EVALUATION METHODOLOGY

We designed distinct evaluation approaches for the three ENRM Project activities (the WSM Activity, the ENRM and SGEF grant facility Sub-activity, and the Shire BEST environmental trust Sub-activity) and for evaluating the ENRM Project as a whole. The approaches combine qualitative and quantitative research methods chosen in response to the research questions and the available data.[9] We summarize the evaluation designs by activity in Table III.1, which includes an abbreviated version of the main research questions, data sources for answering those questions, and the key outcomes of interest. Complete text for all research questions is available at the start of each activity's chapter of findings and in Table A.1, which offers a side-by-side view of the interim research questions (Coen et al. 2019; Velyvis et al. 2019) along with the endline research questions. Although this chapter summarizes our methodology for collecting and analyzing the second round of evaluation data, Coen et al. (2018) offers a more complete description of the evaluation approach.

The remainder of this chapter describes the two evaluation methods used in this report: (1) a **performance evaluation** and (2) an **impact evaluation**. Our performance evaluation methodology is primarily based on qualitative data and is used to uncover processes, perceptions, and explanations. The scope of the performance evaluation is component-specific, especially as project components were at different stages of development over the evaluation period. For example, our evaluations of the WSM Activity and the environmental trust Sub-activity both address implementation specifics, because their implementation had not been fully resolved by the interim evaluation. Our performance evaluations are primarily based on qualitative data, drawing on key informant interviews with employees from MCC, Malawi Millennium Development Trust (MMD), and implementers; site visits; project implementation and monitoring documents; and a review of documents produced since the compact closed. A descriptive trends analysis accompanies the qualitative analysis for data on dredging intensity and costs, which became available only in the post-compact period and are therefore not suitable for an impact evaluation. For these indicators, understanding the direction of change is more informative and reliable than attempting to estimate such change as a function of the ENRM Project. We employ this descriptive approach to identify patterns in time-series data and incorporate insights from the qualitative sources to better interpret the key factors leading to any such observed patterns.

For other WSM Activity outcomes made possible by routine data collection, we carried out an impact evaluation using an interrupted time series (ITS) methodology that we describe in Section III.B.2. The ITS method estimates a pre-intervention trend from routinely collected time-series data for periods before the Activity to make predictions for subsequent periods. We compare those predictions with observed data in the post-Activity period, interpreting the estimated difference between the two as the Activity's impact under a set of assumptions described in Section III.B.4. Using administrative data from EGENCO, we apply this method to outcomes involving electricity and weed and sediment management.

[9] COVID-19 influenced our evaluation approach and limited in-country fieldwork and data collection. Our in-country consultant was able to conduct face-to-face interviews with a subset of interviewees.

Table III.1. ENRM project final evaluation summary

Activity or Sub-Activity: evaluation method	Main research questions	Data sources	Key outcomes
WSM Activity: Performance evaluation and interrupted time series	1. How was the activity implemented? 2. To what extent did the activity restore active storage at the hydropower plants during the compact and after it ended? 3. Did the new weed harvesters and dredgers affect power plant operations and power generation after the compact ended? 4. How do the power plants ensure appropriate maintenance and repair of the equipment provided under the WSM activity? 5. What are stakeholders' perceptions of the sustainability of outcomes of the WSM activity?	• KIIs with former MCA-Malawi, MCC, and EGENCO staff • Administrative data from EGENCO • CHIRPS rainfall data • Site visits to power stations • Project implementation and monitoring documents	• Weeds harvested, costs of weed management • Electricity generation by power station • Turbine outages by power station • Equipment functionality • Facilitators and barriers to implementation and sustainability
Environmental trust: Performance evaluation	1. What implementation factors supported or hindered the establishment of the trust? 2. To what extent is the trust on track to reach administrative, operational, and financial sustainability?	• KIIs with trust staff, board of trustees, MMD, and MCC • Trust document review	• Implementation projects supported by trust funds • Facilitators and barriers to implementation and sustainability • Budget projections
ENRM Project: Performance evaluation	1. Did the ENRM Project achieve its targeted intermediate and final outcomes and contribute to higher-level compact objectives listed below? Why or why not? 2. Based on the results of each activity's evaluation, what are stakeholders' perceptions of sustainability of outcomes achieved under the ENRM project, and why?	• Findings from each activity-level evaluation • Administrative data from EGENCO, and Blantyre and Southern Region Water Boards • KIIs with EGENCO, MMD, MCC, and grantees • Project documentation including compact close-out and post-compact documents	• Electricity generation • Power plant availability •

EGENCO = Electricity Generation Company (Malawi); ENRM = Environmental and Natural Resource Management; CHIRPS = Climate Hazards Group InfraRed Precipitation with Station data; KII = Key informant interview; MMD = Malawi Millennium Development Trust; WSM = weed and sediment management.

A. Performance evaluation

A performance evaluation is a descriptive study that addresses project objectives, achievements, implementation, sustainability, and other research questions related to project design, management, and operational decision making (MCC 2017). The performance evaluations presented in this report examine whether an Activity or Sub-activity achieved its intended outputs and outcomes, and the factors that supported or inhibited its implementation and sustainability. We collected several types of data from a variety of stakeholders, enabling us to triangulate findings between sources by systematically categorizing the data to identify convergent and divergent themes and patterns. In this section, we describe our qualitative, quantitative, and administrative data collection, then explain our analytic approaches to evaluating the performance of each activity.

1. Qualitative data collection

To answer our research questions, we conducted key informant interviews with key project stakeholders, including staff from MCC and MMD; EGENCO plant operators, managers, and executives; and staff and board members from Shire BEST. Table III.2 summarizes our qualitative sample, the number of interviewees from each respondent group, and the content domains covered in the interviews. In addition to interviewing key stakeholders, we made site visits to Liwonde Barrage to observe the weed-harvesting equipment and activities, and to Kapichira to assess dredging equipment and activities.

Table III.2. Final evaluation key informant interviews by respondent type

Respondent type	Number of interviewees	Domains covered
Shire BEST trustees	2	• Trust operations and grant-making • Implementation successes and challenges • Board organization and roles
Shire BEST staff	2	• Trust operations and grant-making • Financial sustainability • Status of fundraising efforts
EGENCO staff	10	• Operational status of WSM equipment • Equipment maintenance procedures • Effects of equipment on EGENCO operations
MCC staff MMD staff	1 1	• WSM implementation, results, and sustainability • Trust implementation, results, and sustainability • Grant facility implementation, results, and sustainability

BEST = Basin Environmental Support Trust; EGENCO = Electricity Generation Company (Malawi); MCC = Millennium Challenge Corporation; MMD = Malawi Millennium Development Trust; WSM = weed and sediment management.

We developed semi-structured interview guides for each respondent type. We mapped questions in each interview guide to the evaluation research questions listed in Table III.1. We designed interviews to elicit participants' perceptions of Activity or Sub-Activity implementation, outputs and outcomes, and sustainability beyond the compact. For project components that had not yet been implemented by the interim data collection round—notably, the dredging investments and the environmental trust—we asked interviewees about actual and planned implementation, reasons for deviating from planned implementation, and successes and challenges of implementation. We also asked questions specific to each activity evaluation. For the WSM Activity evaluation, we explored how EGENCO conducted WSM before procuring new equipment and about the maintenance and repair plans for the new equipment. For the evaluation of the environmental trust, we focused on successes and challenges establishing sustainable funding, grants the trust has made since it began its operations, the role and support provided by the trust's board of directors, and other operational and administrative processes.

An in-country consultant and U.S.-based researchers conducted the interviews in English. When participants provided informed consent, we audio-recorded interviews and transcribed them for subsequent analysis. We reviewed transcripts (from the recording or from notes taken during the interview) to both code key themes emerging from the conversations and to identify quotes from interviewees that we considered to be particularly illustrative or informative.

2. Quantitative and administrative data collection

We complement the qualitative data with quantitative and administrative data sources to support the performance evaluation, as listed in Table III.3. We use administrative data from EGENCO on sediment management activities at Kapichira (which unlike weed harvesting at Liwonde were not already occurring prior to MCC's WSM investments), along with water quality data from the water boards as control variables for the ITS models. To identify whether project components achieved compact targets, we rely on monitoring data from MCC and administrative data from EGENCO. For the environmental trust performance evaluation, we used key documents shared by Shire BEST, including its strategic plan and minutes from recent board of trustees and subcommittee meetings.

Table III.3. Description of quantitative and administrative data sources

Data source	Description
EGENCO	Monthly data on weed and sediment management activities
Blantyre and Southern Region Water Boards	Monthly data on water quality indicators for three sites along the Shire River (Liwonde, Mangochi, and Walker's Ferry)
MCC	Indicator tracking table
MCC and Shire BEST	Trust feasibility study, trust strategic plan, audited financial statements, meeting minutes from board of trustees and subcommittee meetings

BEST = Basin Environmental Support Trust; EGENCO = Electricity Generation Company (Malawi); MCC = Millennium Challenge Corporation.

3. Overview of analysis

For each performance evaluation, we used a variety of analytic methods (Table III.4) to address each of our research questions. Below, we describe these methods and how we applied them to the research questions.

Table III.4. Performance evaluation analytic methods by evaluation activity

Analytic methods	WSM activity	Environmental trust	Overall ENRM project
Data triangulation	X	X	X
Descriptive trends analysis	X		X
Document review	X	X	X
Cross-evaluation data synthesis			X
Logic model assessment	X	X	X

We used data triangulation throughout the analyses to assess corroborating and discrepant findings among various data sources, including key informant interviews, activity documentation, administrative data, and direct observations. For example, when analyzing implementation barriers for the environmental trust, we compared data from interview transcripts with MCC and MMD staff, trust board members, trust staff, trust documents, and board meeting minutes, assessing convergent and divergent findings.

As part of the WSM Activity evaluation, we conducted a descriptive trends analysis of data provided by EGENCO. We examined outcomes that were available only in the post-compact period, such as the amount of sediment removed at Kapichira, and outcomes that were available over a longer duration, such as the total amount of electricity generated by quarter. These indicators were likely affected by confounding factors that could not be properly accounted for in an impact evaluation framework.

In addition to evaluating each Activity or Sub-Activity as an independent entity, we also carried out a cross-evaluation data synthesis that examines the effect of the ENRM Project as a whole—both as the synthesis of independent activities and accounting for any interactions among them—on outcomes of interest and the compact objective.

We assessed the logic model by comparing each of its components with the information we obtained throughout our evaluation. Our assessment was guided by questions about whether the logic model properly captured the observed relationships and requirements as depicted in the program logic, and whether the initial logic model failed to capture any key relationships that turned out in practice to be important. The results of this assessment could then inform the design and understanding of similar interventions in other settings.

All quotes in this report are coded by type of interview along with a unique ID number to aid confirmability of the research, which is a criterion of validity in qualitative research.[10]

[10] We use the following quote codes: MCC = MCC staff or consultant; MMD = staff at the Malawi Millennium Development Trust; BM = Shire BEST staff or board member; ES = EGENCO staff.

B. Impact evaluation

For the evaluation of the WSM Activity, in addition to the performance evaluation, we conducted an impact evaluation using an ITS design. For several outcomes of interest for the WSM Activity evaluation—including the volume of weeds harvested and the quantity of hydroelectricity generated—we used time-series data from before the project began to forecast a counterfactual of how those outcomes would have evolved without ENRM investments. We then estimated the direction and magnitude of the investment's impacts by calculating the difference between the values observed in the treatment period and the forecast values. Below we detail the key outcomes, data sources, and empirical approach.

1. Key outcomes

We assessed the impact of the WSM Activity on two domains: (1) physical efforts intended to increase head pond water storage capacity and (2) the amount of electricity that could not be produced because of problems caused by weed and sedimentation. Table III.5 describes the measures of interest under both domains.

Table III.5. Outcome domains and measures for the WSM impact evaluation

Domains	Measures
Effort to increase water storage capacity	• Monthly cost of weed management (adjusted for price inflation, in US$) • Monthly cost of sediment management (adjusted for price inflation, in US$)
Electricity generation	• Monthly electricity not produced by hydropower plant due to weeds (MWh) • Monthly electricity not produced by hydropower plant due to sedimentation faults (MWh) • Monthly hours of no generation due to weeds; monthly hours of no generation due to silt

To control for multiple hypothesis testing, in which a subset of estimates are found to be statistically significant by virtue of the number of statistical tests performed despite a true impact of zero (that is, false positives), we took a balanced approach that reduced the risk of false positives while avoiding false negatives. Earlier, we worked with MCC and MCA-Malawi to identify a small number of primary outcome measures within each domain that we used to test the main hypotheses of the impact analysis and to minimize multiple hypothesis testing concerns.

2. Interrupted time series design

As Coen et al. (2018) describes, we use an ITS design to estimate project impacts. With this analytical approach, we compare data covering a post-treatment period for an outcome of interest with values from a pre-treatment period. The ITS method uses the pre-treatment data to estimate a trend function and predicted values for the post-treatment period under the assumption that pre-existing trends would continue without MCC's interventions. Those predictions serve as the counterfactual against observed data, the difference of which is estimated as the treatment effect. Equation 1 is the primary specification we used for presenting results in which *t* indexes time from the start of our analysis.[11] The *Post* indicator switches on in the month following initial operation of the relevant equipment, which is May 2018 for weed harvesting in Liwonde and April 2020 for dredging in Kapichira. We control for both

[11] For some outcomes, because the data we received might go as far back as 2006, we trimmed pre-treatment data to begin at January 2010. If these models were run with complete data available, our counterfactual values would be influenced as much by data from a decade before the compact began as data from the years immediately preceding the compact, thereby skewing the anticipated rate of change if no ENRM activities were implemented.

contemporaneous and lagged rainfall as the model's time-varying variables (X_t), because rainfall levels are plausibly related to both conditions affecting hydropower productivity (for example, influencing the volume of weeds and sediment that are carried into the river) and overall reservoir availability, which affects hydropower operations.

$$(1) \qquad y_t = \beta_0 + \beta_1 Time_t + \beta_2 Post_t + \beta_3 Time_t * Post_t + \boldsymbol{\alpha} X_t + \in_t$$

Our estimation procedure allows the ENRM treatment to affect outcomes in two ways: (1) a stepwise change that is averaged over the entire post-treatment period (β_2) and (2) a change in trend over time (β_3). Negative β_3 values indicate a reduction in the trend rate over time, whereas a positive β_3 value represents an increase relative to the pre-treatment trend value (β_1). For interpretation, β_2 is an estimate of how much y_t changes between the pre- and post-treatment periods, while β_3 is a slope estimate that reports how much y_t changes per time step in the post-treatment period. β_3 should be interpreted relative to β_1 which is the slope term for the entire time period, both pre- and post-treatment. To illustrate, given regression results that estimate β_1 as -1.15, each time step reduces the dependent variable by 1.15 units. If β_3 were estimated as 3, then each time step in the post-treatment period would increase the dependent variable by 1.85 units because then we are accounting for the -1.15-unit change in all time periods combined with the 3-unit change that takes effect only in the post-treatment period. Although we believe this primary specification offers an attractive balance between flexibly estimating ways the program could influence outcomes, in both levels and rates over time, we also recognize that alternative specifications might control for other important aspects. We therefore conducted a series of robustness checks for key outcomes by toggling the inclusion of controls such as contemporaneous raw water turbidity values at the Walkers Ferry monitoring station and the contemporaneous and first lagged month turbidity values from the Liwonde station, and the inclusion of monthly fixed effects.[12] Those results are available in the corresponding appendices.

3. Data sources

The WSM impact evaluation is primarily based on monthly administrative data EGENCO collected and shared with the evaluation team. For data on the timing of delivery, installation, and start of use of the equipment provided under the WSM activity, we relied on updates from MCC, interviewees, and post-compact monitoring and evaluation reports compiled by the Ministry of Finance, Economic Planning, and Development. We control for the influence of precipitation on outcomes by including both contemporaneous and lagged rainfall measures. Because it is likely that outcomes for any given HPP result from both local rainfall and rainfall upstream, we apply a common approach of using monthly rainfall data as measured at Liwonde, the most upstream location of interest, across all of our ITS models. The rainfall data comes from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data set (Funk et al. 2015). As described above, we also run regression models that control for water turbidity, both at Walkers Ferry, which is immediately upstream of the Nkula HPP, and at Liwonde,

[12] Due to missing observations in the Walkers Ferry water quality data, our model sample shrinks by more than 10 percent when including turbidity into a regression. We therefore report these results as robustness checks and not as the main specification.

which is much further upstream of all three HPPs. This data was obtained from the Blantyre and Southern Region Water Boards at a monthly resolution.

4. Overview of analysis

We measured the impact of the WSM Activity on key outcomes by calculating the difference between predicted outcome levels based on the pre-implementation period trend without the project, and the actual outcome levels observed in the post-implementation period. For example, to measure changes in the amount of "electricity not produced because of weeds and sediment," we determined the counterfactual by projecting the loss of electricity production post-WSM equipment use from the pre-WSM equipment period trend. To estimate the impact of the WSM activity, we then calculated the difference from this predicted loss of electricity production with the actual loss of electricity production observed after WSM equipment use. We used a regression framework, controlling for other time-varying factors that might have influenced outcomes, to estimate changes more accurately in WSM Activity outcomes of interest. We report the average treatment effect as the mean difference between the counterfactual fitted value and the model fitted value for all time steps in the post-treatment period.

To examine whether Activity benefits varied by location, we estimated impacts separately by HPP, because factors related to their upstream and downstream placement necessitated independent analyses. For example, we assessed outcomes at the Kapichira site separately from Nkula and Tedzani, which can serve as falsification tests, because the WSM dredging activity at Kapichira should have no operational effect on the upstream HPPs. By independently analyzing Kapichira, we can test whether the dredging activity affected only that HPP, whereas combining outcomes of all HPPs into one measure would obscure the location of any estimated changes.

5. Exposure period

The exposure period for outcomes is specific to each intervention. Since the weed management equipment at Liwonde became operational in May 2018, we have been able to observe outcomes up to approximately 3.5 years afterward (through December 2021). Dredging operations began at Kapichira in April 2020, and we therefore have a shorter period of 1.5 years to observe impacts. For both interventions, improvements in hydroelectricity productivity would be immediate and increasing in magnitude over time as the underlying problem—excess weed undergrowth or sediment deposition volume—is resolved.

6. Limitations

We note two important assumptions to make explicit when discussing the interpretation of ITS analysis results. First, the accuracy of ITS estimates is predicated on having controlled for all important exogenous factors that might cause changes in the outcome of interest. For example, if non-MCC programs began implementation in the treatment period and were unaccounted for, then their influence on outcomes would be incorrectly attributed to MCC's investments. Conversely, if post-compact changes in land-use practices exacerbated erosion levels, our results would underestimate MCC's impact.

A key concern here might be the role of the World Bank's Shire River Basin Management Program (SRBMP) given that it also funded catchment management activities in the Shire River basin and operated in roughly the same timeframe as ENRM investments. However, the World Bank's implementation completion report indicates that rehabilitation activities (e.g., soil and water conservation, conservation agriculture practices, and stream and water control) were completed on roughly 35,000 hectares, or 1.3 percent of the Shire River basin's land area (World Bank 2020). Contextualizing this footprint within the entire basin, it is unlikely these activities would be the primary cause for any reduction in weed and sediment accumulation affecting EGENCO's HPP operations. Relatedly, while the SRBMP supported the development of water and land management plans encompassing 129,000 hectares, that total is 5 percent of the basin's area (World Bank 2020). Only a portion of those areas were likely full adopters of the plans and successfully executing effective SLM practices. In short, our estimates below will unavoidably include contributions from the SRBMP to the degree that SRBMP activities affected the operating conditions of EGENCO's HPPs and produced benefits that disproportionately occurred in the treatment period. However, given the scale of their activities and their indirect nature, compared to the direct role of weed and sediment removal, we believe it is safe to assume the SRBMP's contribution is not the dominant explanation for any observed improvements in HPP performance.

Second, we acknowledge that a significant confounder of our analyses is the effect that COVID-19 has had on employee availability and productivity. However, because COVID has occurred only in the post-compact period and it is likely that it would only worsen outcomes, any estimates we present are underestimated effects of how the investments and equipment would have performed had there been no pandemic.

IV. FINAL FINDINGS FROM THE WEED AND SEDIMENT MANAGEMENT ACTIVITY EVALUATION

Summary of key findings

Implementation

- The WSM Activity funded the purchase of new weed removal equipment at the Liwonde Barrage that supplements equipment that had already been in operation. The new equipment has likely had synergistic effects with assets the World Bank purchased independently through its own weed management activities, which also focus on the Shire River Basin.
- The Activity also procured a dredge for the Kapichira power station that began operations in April 2020 after delays caused by the completion of the sediment disposal area and necessary modifications to the dredge's main engine.

Results

- The two new weed harvesters have led to a substantial increase in the total volume of weeds removed at the Liwonde Barrage; for 2019 through 2021, an annual average of nearly 29,000 tons of weeds were removed, exceeding the 2012-2013 baseline by 274 percent.
- Dredging operations since April 2020 have removed more sediment than envisioned in the sediment management plan. However, EGENCO plans to sustain its capital dredging plan for up to five years in total before transitioning to maintenance dredging.

Impacts

- HPPs experienced fewer hours of weed-caused plant downtime and fewer megawatt-hours of lost generation after the arrival of the new harvesters.
- Sediment-induced hydroelectric losses, both in electricity generation and hours of operation, dropped to zero even before Kapichira dredging began, indicating that other factors contributed to the dredging's effect on improved HPP performance.

Sustainability

- Lengthy delays in receiving spare parts caused by complex procurement processes and overseas shipments mean that staff must be proactively ensuring that parts purchases are submitted early enough to avoid harvester downtime.
- As the Kapichira disposal site fills, new disposal plans must be developed for dredging operations to continue at their current rate.

Delays in the delivery of the WSM Activity equipment meant that there was little evidence about equipment operation and performance available at the time of our interim evaluation. Our earlier report (Coen et al. 2019) therefore focused on implementation of the Activity and identified threats to sustainability based on the information available at the time. Since then, data on operations and outcomes of interest have been collected continuously by EGENCO, and key stakeholders have gained personal experience in either operating the WSM equipment or observing the results of the equipment. In this final evaluation, we present evidence on Activity implementation, the performance of weeding and dredging activities, the degree to which they affected outcomes of interest, and the key sustainability drivers that will determine whether Activity benefits will persist. This chapter leans heavily on administrative data provided by EGENCO and on interviews we conducted with EGENCO technical staff and leaders, and stakeholders from MCC and MMD. The chapter is organized according to the WSM Activity evaluation research questions listed in Table IV.1.

Table IV.1. Research questions addressed in the WSM Activity evaluation

Research question
1. How was the Activity implemented?
a. How did actual equipment purchase deviate from the original plan? How did the plan change due to other donor funded interventions at the Liwonde Barrage?
b. Did the equipment actually purchased perform as expected in terms of the quantities of sediment dredged and weeds harvested?
2. To what extent did the Activity restore active storage at the hydropower plants during the compact and after it ended?
a. How did implementation of the dredging operations and disposal compare to the sediment management strategy?
3. Did the new weed harvesters and dredgers affect power plant operations and power generation after the compact ended?
a. How did the use of actually purchased equipment and related improvements vary by hydropower plant?
4. How do the power plants ensure appropriate maintenance and repair of the equipment provided under the WSM Activity?
5. What are stakeholders' perceptions of the sustainability of outcomes of the WSM Activity?

A. Weed-harvesting activities

In this section, we report our key findings on the weed-removal activities that have taken place at Liwonde Barrage, upstream of the Shire River cascade and 50 miles upstream of Nkula (Figure I.2). In Section IV.A.1 we describe the equipment purchased to support weed removal activities and deviations in implementation against the original plans. We then assess activity performance by analyzing weed removal volumes and the activity's operating costs in Section IV.A.2. In Section IV.A.3, we share the results of the ITS models to understand the impact of weed removal operations on HPP outcomes. Section IV.A.4 addresses the potential challenges to sustaining the gains made from weed harvesting and removal.

1. Findings of post-compact implementation

RQ 1. How was the activity implemented?

RQ 1a. How did actual equipment purchase deviate from the original plan? How did the plan change due to other donor-funded interventions at the Liwonde Barrage?

As Coen et al. (2019) describe, the weed-removal equipment received at Liwonde exceeded the compact plans. Instead of the planned target of purchasing one new harvester and rehabilitating a harvester that had been in operation at Liwonde since 2005, two new diesel-powered weed harvesters (Figure IV.1) were procured in 2018. MCC investments complemented the harvesters with two tipper trucks (Figure IV.2) and one conveyor belt (also Figure IV.1). As a result, the Liwonde site currently has four harvesters, five tipper trucks, and two shore conveyors to offload weeds collected by the harvesters onto the tipper trucks. MCC also funded the addition of small trash barriers at the intake of the Nkula HPP to block weeds from the intake screens.

Figure IV.1. The two harvesters and a shore conveyor at Liwonde

Figure IV.2. Large and small tipper trucks supporting weed removal at Liwonde Barrage

EGENCO had recommended purchasing equipment from the Wisconsin-based Aquarius Systems, because its existing harvesters were manufactured by Aquarius, and EGENCO staff were experienced in operating them. Interviewees stated that EGENCO's familiarity with the equipment facilitated communications with Aquarius, who was responsive to the needs required for operations at Liwonde. For example, the procured harvesters had stainless steel hulls, which are more resistant to corrosion and impact than standard mild steel hulls. Similarly, shore conveyor motors were upgraded to handle the load weight of heavy weeds, especially hippo grass, that would otherwise require laborious, manual offloading and cause conveyance slowdowns. When the new harvesters arrived, 12 EGENCO employees were directly involved in receiving, offloading, and assembling the equipment. Those employees received hands-on training in equipment usage from Aquarius staff.

The most visible deviation relative to the original weed management implementation plan was EGENCO having to relocate its weed disposal site. EGENCO's initial weed management plan had been to dump weeds into a forest reserve adjacent to Liwonde National Park. The local traditional authority later identified a quarry area near Luwangwa village as a substitute disposal site. After the village headman passed away, the local community began demanding 18 million MWK in compensation from EGENCO to dump at that location and actively blocked EGENCO's access to the site. These tensions were remedied when EGENCO relocated its weed disposal. Interviewees reported that the district assembly connected EGENCO with an individual who was willing to receive compensation in exchange for giving EGENCO the right to dump weeds in that location. Neither the earlier nor the current weed disposal site has been fenced off or guarded by security, despite MCC recommending fencing. While the management plan intended for communities to have some access to disposed weeds to use as compost, the lack of site security has meant that communities have open access. MCC had also recommended the construction of a perimeter berm to prevent rains from washing weeds back into the river, but none has been constructed.

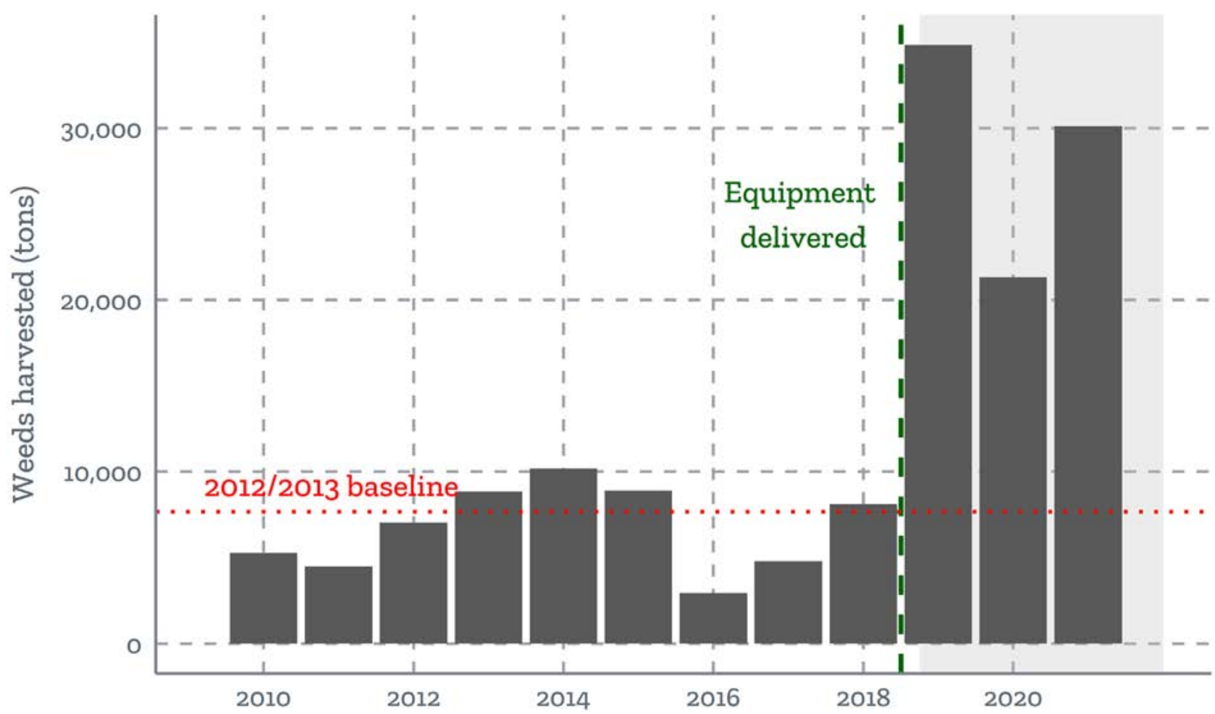
Interviewees stated that the World Bank's investments in weed management did not impact which equipment was procured or how EGENCO has used the equipment. However, they did note that investments purchased through the World Bank's SRBMP Phase 1 Project have created unplanned synergies with the new MCC-funded WSM equipment, particularly the Kamuzu barrage weed barrier and a mechanical jib crane. These assets have improved the effectiveness of both weed trapping and weed removal that can occur at Liwonde. The World Bank equipment has been a substantial improvement over previous weed barriers that would snap from the weight of accumulated weeds, leading to their release downstream.

2. Performance of weed-removal activities

RQ 1b. Did the equipment actually purchased perform as expected in terms of the quantities of weeds harvested?

Although MCC did not have an end-of-compact target for the volume of weeds to be removed at Liwonde Barrage, the annual tonnage removed has substantially increased since the equipment began operating in May 2018. From 2019 through 2021, an annual average of nearly 29,000 tons of weeds were removed, which is 274 percent higher than the baseline (2012–2013) value of 7,684 tons (shown in dashed red line), as shown in Figure IV.3.

Figure IV.3. Annual tons of weeds removed at Liwonde Barrage



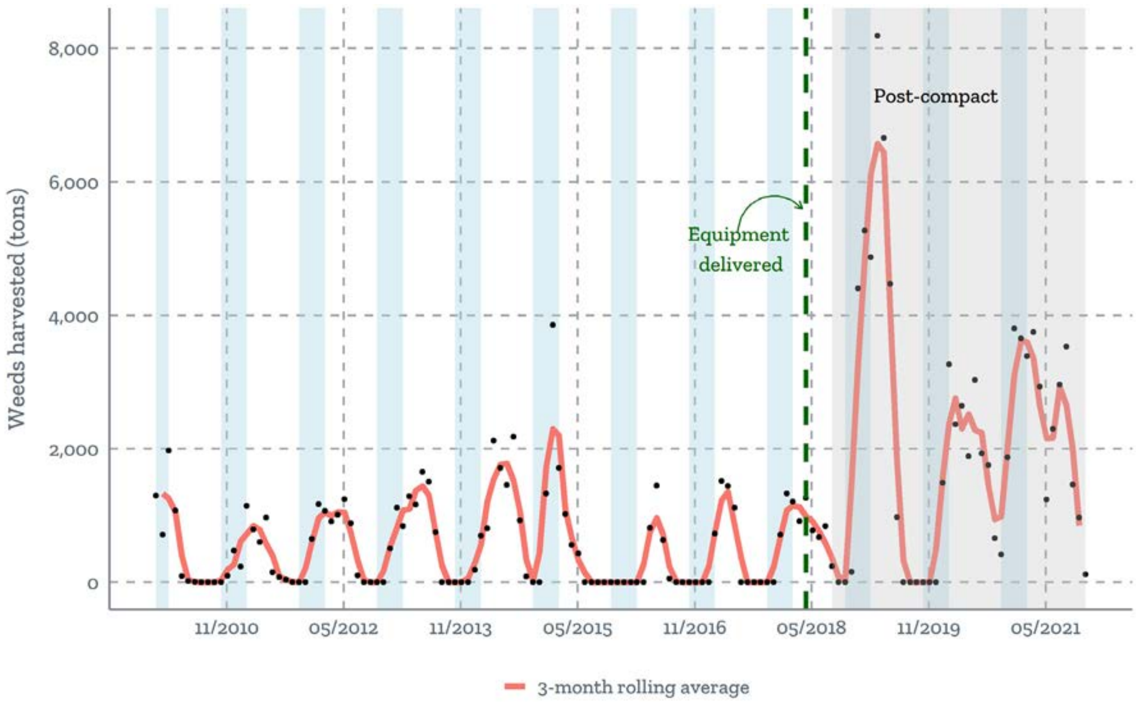
Source: Mathematica calculations using data from EGENCO.

Note: The weed-harvesting equipment was considered fully delivered to EGENCO as of May 2018. The compact formally closed in September 2018, and the gray box denotes the post-compact period. N = 12 annual observations for 2010 through 2021.

Weed-removal totals have increased because of increases in monthly removal capacity and fewer idle months with the harvesters not in operation. We note two key changes driving the post-compact increase in annual weed removal totals. First, the tonnage of weeds that can be harvested each month has increased over time, as seen in the upward shift of maximum values in Figure IV.4 during the post-compact period. From 2009 to the arrival of the new weed removal equipment, only one month saw more than 3,000 tons of weeds harvested (February 2015), while nearly 30 percent of all months since March 2018 have seen 3,000 or more tons harvested. Second, before the new equipment, weeding activities were commonly halted, as seen in the frequency of observations with 0 tons harvested on the horizontal axis. These stoppages would often continue for several months in a row, such as August 2010 through November 2010; the longest spell was July 2015 to April 2016. These down periods have tended to cluster in October, November, and December, which marks the end of the dry season and the start of the rainy season. Weed-removal activity tends to peak in March, April, and May, when the rainy season has concluded and transported weeds from the Basin to the barrage, and when nutrient loads have created conditions that are likely to be conducive to weed overgrowth.[13] However, after the new equipment arrived, months of no weeding activity have more than halved, from 40 percent of all months (40 of 100 months) to 18 percent (8 of 44 months).

"We didn't expect to be performing or to be harvesting like this, as the new harvesters have allowed us to do." (ES4)

Figure IV.4. Tons of weeds harvested per month at Liwonde Barrage



Source: Mathematica calculations using data from EGENCO.

Note: Vertical light blue bars denote the rainy season, which spans November through February. The weed-harvesting equipment was considered fully delivered to EGENCO as of May 2018. The compact formally closed in September 2018, and the gray box denotes the post-compact period. N = 144 monthly observations for January 2010 through December 2021.

[13] Nutrient cycling upriver of Liwonde may contribute to the development of weed nursery areas whose growth dynamics are unrelated to seasonal timings. As a result, we would anticipate that there is no sustained portion of the year lacking weed accumulation, and that weed growth would need to be managed throughout the year.

EGENCO's monthly expenditures on weed management at Liwonde, in constant MWK, has increased in the post-compact period. Over the 2013–2021 period, monthly expenditure reached a low in February 2017, then steadily increased through to the point of receiving the new weed harvester (Figure IV.5). Although month-to-month variability in expenditures is higher in the post-compact period, which is likely related to the increased variability in monthly harvesting volumes as shown in Figure IV.7, the overall mean monthly expenditure is higher, as well. Between July 2013 and April 2018, EGENCO's average monthly weed management costs were 14.8 million MWK (USD 20,271), rising to 30.43 million MWK (USD 41,679) from May 2018 through December 2021.[14]

Figure IV.5. EGENCO's monthly weed management costs at Liwonde Barrage (in million 2017 MWK)

Source: Mathematica calculations using data from EGENCO.

Note: We calculate constant 2017 MWK using the annual GDP deflator series available through the [World Bank World Development Indicators] and linearly interpolating at the monthly level. The MWK:USD exchange rate for July 1, 2017 was 730.1:1, as per https://www.xe.com/currencytables/?from=MWK&date=2017-07-01#table-section. N = 96 monthly observations for July 2013 through June 2021.

EGENCO's engineering staff report that there have been no major problems with the newly procured weed harvesters. They stated that there has been no significant equipment downtime, and they have had spare parts to replace equipment as needed.

[14] All expenditures were reported by EGENCO in current MWK. We deflated costs to constant 2017 MWK using the annual GDP deflator series available through the World Bank World Development Indicators and linearly interpolating at the monthly level. Expenditure equivalents in U.S. dollars were calculated using the July 1, 2017 exchange rate of 730.1 MWK to 1 USD.

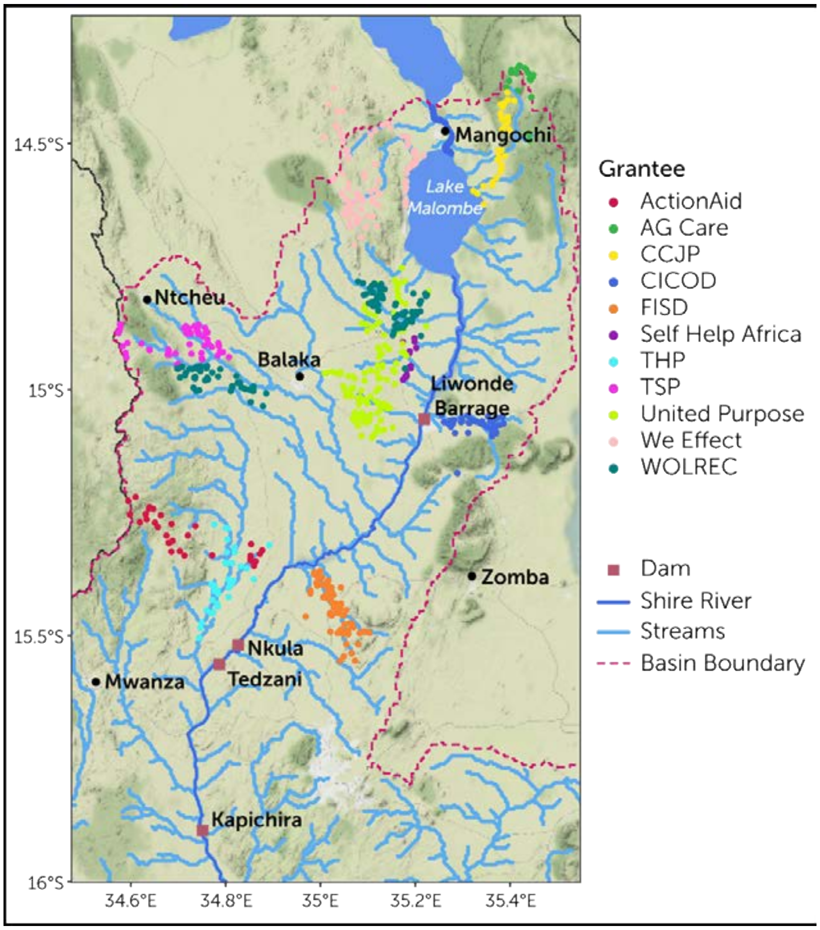
3. Impacts of weed-removal activities on electricity outcomes

RQ 3: Did the new weed harvesters affect power plant operations and power generation after the compact ended? How did the use of actually purchased equipment and related improvements vary by hydropower plant?

To determine whether weed-removal activities have impacted electricity generation, we conducted an ITS analysis to examine two types of outcomes that relate to HPP performance. First, we examined whether HPPs experienced a reduction in the amount of electricity *not* produced because of weeds. We also examined the total number of hours of lost generation experienced by each hydropower plant due to weed-related problems. For both types of outcomes, we used HPP-specific data for Nkula, Tedzani, and Kapichira, following their relative order in the Shire Cascade and consequently the sequence through which the Shire River flows through them (as shown in Figure IV.6).[15] In each ITS model, we set the treatment period (also referred to as the "post" period to denote the period after the treatment began) to begin in June 2018, which is the first full month in which the compact-funded weed-harvesting equipment was operating at Liwonde. As our focus in this set of analyses is how the weed harvesting equipment affected electricity generation, our approach conceptually identifies *treatment* as the time during which MCC-funded weed-removal investments could have had beneficial effects on HPP operations. As we do not have data on weed removal totals at Nkula HPP, we are not able to perfectly attribute observed changes in HPP performance between the Liwonde WSM investments and the small trash barriers at Nkula. Given that the Liwonde weed harvesters and conveyor belt are likely to have a weed removal capacity at least one or two orders of magnitude greater than the Nkula trash barrier, we believe it is safe to assume that the majority of any observed reductions in weed-caused electricity losses are due to the WSM activities in Liwonde.

[15] EGENCO calculates lost electricity subtotals separately from weeds and from silt. In Section IV.B.3, we report analogous results for silt-based electricity losses.

Figure IV.6. Map of HPP locations along the Shire River



The weed-harvesting equipment contributed to an overall reduction in weed-caused electricity losses at each of the Shire Cascade HPPs. At each plant, the fitted ITS trend, shown as the dark blue line in Figure IV.7, is lower than the predicted counterfactual, shown as the light blue dotted line, in each of the post-treatment months. The positively sloped pre-treatment trends indicate that losses were likely to continue rising if new equipment had not been provided at Liwonde. Although the pre-treatment trends among the three HPPs suggest that losses at Nkula would have been the highest, at the rate of an additional 4.6 MWh (Table IV.2) in each subsequent month, none of the estimated ITS parameters are statistically significant, and trend values are very sensitive in the face of highly variable data.

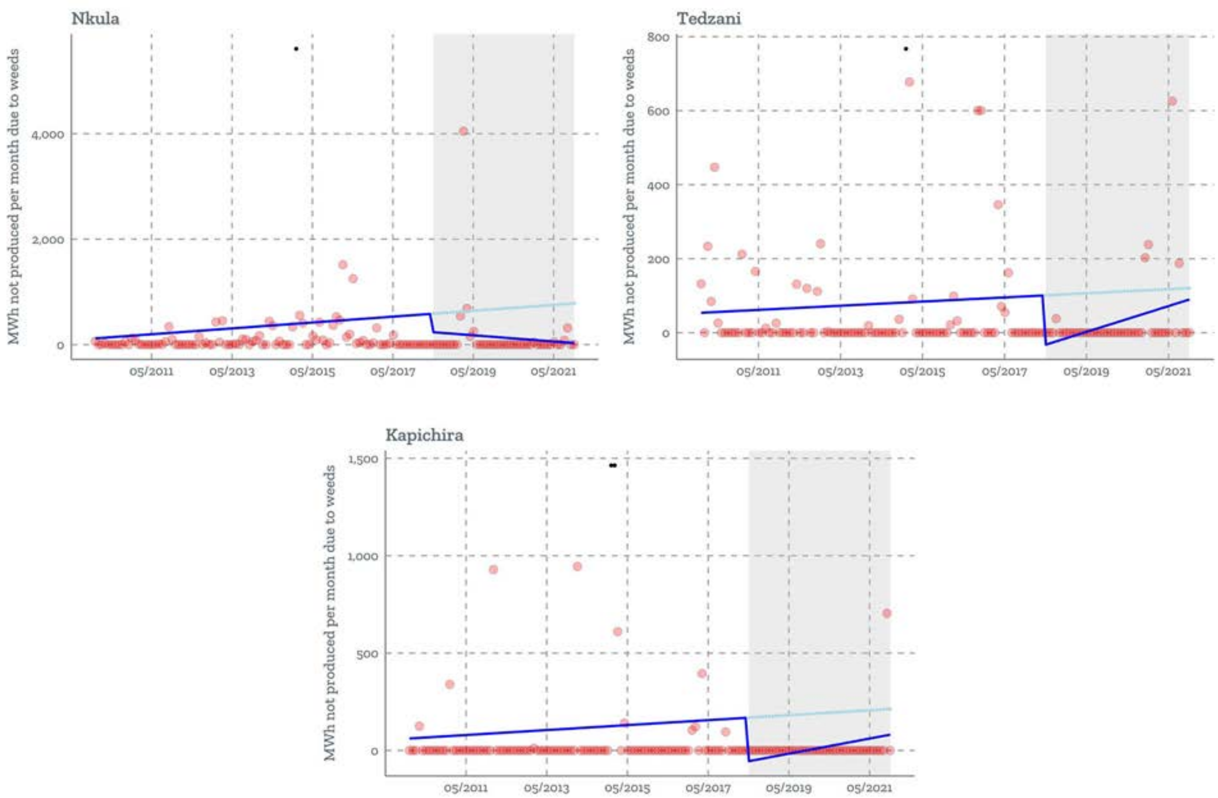
The treatment period reduction did not occur abruptly following equipment delivery; several months of no weed-induced losses preceded the treatment period for both Nkula and Tedzani. Another observable difference following the start of new equipment operations is the absence of extreme outlier months in which losses exceeded the monthly mean by at least two standard deviations. Those months are few and top-coded and displayed as black points.

Among the three HPPs, the Nkula plant experienced the largest absolute reduction in average monthly megawatt-hours not produced because of weeds, dropping from 355 MWh to 144 MWh in the post-compact period (Table IV.2, Rows 8 and 9). This finding aligns with Nkula's first position in the Shire Cascade, making it the plant most likely to benefit from weed removal at Liwonde. By comparison, the further downstream HPPs would also be contending with weeds transported into the

Shire River along any area between Nkula and itself. Kapichira's *relative* 86 percent reduction (from 117 MWh to 16 MWh) was the largest among the three HPPs.

The upward-sloping, post-compact trends observed for both Tedzani and Kapichira (the dark lines within the gray treatment period rectangle) are caused by losses at the end of the study period that are substantially larger than losses in the earlier portion of the post-compact period. For example, in a handful of months after 2020, losses at the Tedzani HPP exceeded 200 MWh; the largest monthly loss in the early part of the post-compact period was less than 40 MWh.

Figure IV.7. ITS results for megawatt-hours of electricity not produced per month due to weeds, by hydropower plant



Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

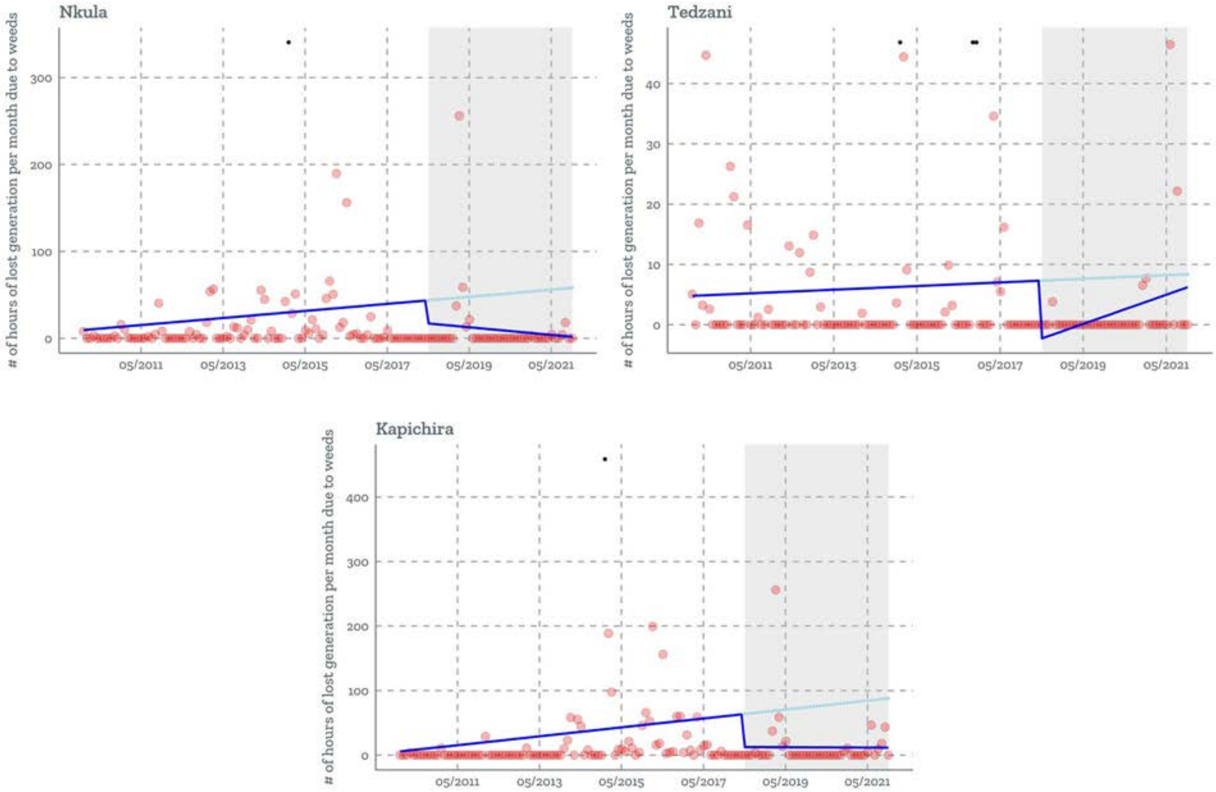
Note: The gray rectangle denotes the post-treatment period, which starts in June 2018, the first full month of operations using the MCC-funded weed harvesting equipment. Outlier values that are two or more standard deviations from the sample mean value for that HPP are displayed in black for improved interpretability. The dark blue line depicts the fitted results from the main ITS specification, holding contemporaneous and lagged monthly precipitation at sample mean values. All regression models include a trend term, a post indicator to denote the post-treatment period, an interaction of the trend term and the post indicator, and contemporaneous and lagged rainfall as measured at Liwonde. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021.

HPPs experienced fewer hours of weed-caused plant downtime without generation after the arrival of the new harvesters. Across the three locations, the positive pre-treatment fitted trend (in blue) indicates that absent the Liwonde investments (Figure IV.8), HPP downtime would have continued increasing in the treatment period, albeit at a substantially smaller monthly growth rate of 0.025 hours each additional month at Tedzani (Table IV.2, row 2). The treatment period is associated with a drop in the average monthly hours of plant-level generation downtime from the low of 10 hours (Tedzani) to 51 (Kapichira) (Table IV.2, row 1). Although those results suggest a sizable stepwise drop coinciding with the treatment period, across all locations, there was still substantial month-to-month variability in post-treatment losses. This variability is particularly noticeable at Tedzani, where conditional on a post-treatment month experiencing some amount of lost generation (that is, above the horizontal axis), the magnitude of such losses is comparable to the magnitude of losses in pre-treatment non-zero loss months. Kapichira, despite being the most downstream from Liwonde, saw the largest reduction in downtime, from an average of 34 hours/month before the harvesters were operational, to 12 hours/month afterward (Table IV.2, Rows 7 and 8). The mean difference in avoided losses between the pre- and post-periods at Nkula and Tedzani are smaller than Kapichira's in levels, but at 63 and 67 percent, respectively, are comparable in rates.

As with several of the subsequent ITS results, the "Post" and "Post x Time" coefficients of interest, which respectively capture immediate level and gradual slope effects of the intervention, are not statistically significant at the 5 percent level. On these grounds, we are unable to reject the hypothesis that the intervention had no effect on HPP outcomes based on this empirical specification. Aside from the relatively small sample size, which reduces analytical power and ceteris paribus decreases the chances of obtaining statistically significant results, another key factor driving the lack of statistical significance is the abundance of zero values in the pre-period. In turn, the pre-treatment period is noisily estimated given the absence of a clear trend line (as in, there is substantial bunching at zero combined with quasi-randomly selected months of large positive values, which prevents the emergence of a clear pre-trend upon which the value of the ITS method is assumed), which reduces the likelihood of finding significant effects on either the "Post" or the "Post x Time" terms. We do not think the lack of statistical significance in these models should detract from the often-unambiguous qualitative takeaway afforded by visual examination of the monthly data. Improvements in HPP performance in the post-treatment period are often very clearly visible. In the accompanying regression tables, this is confirmed by the difference in means between pre-treatment and post-treatment values. We believe the focus in interpreting these results should be on the point estimates, and their relative magnitudes, and less on whether their 95 percent confidence intervals are exclusively positive.

As with the previous ITS results that analyzed electricity not generated because of weeds, we note that over the several months preceding the equipment arrival there were zero losses through to the equipment's arrival. This finding suggests that other factors, aside from MCC's investments, likely contributed to the improved performance that is observed in the treatment period.

Figure IV.8. ITS results for hours of hydropower plant production lost per month due to weeds, by hydropower plant



Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: The gray rectangle denotes the post-treatment period, which starts in June 2018, the first full month of operations using the MCC-funded weed harvesting equipment. Outlier values that are two or more standard deviations from the sample mean value for that HPP are displayed in black for improved interpretability. The dark blue line depicts the fitted results from the main ITS specification, holding contemporaneous and lagged monthly precipitation at sample mean values. All regression models include a trend term, a post indicator to denote the post-treatment period, an interaction of the trend term and the post indicator, and contemporaneous and lagged rainfall as measured at Liwonde. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021.

Table IV.2. Regression results for ITS models of weed-induced HPP losses

Row #	Variable	Megawatt-hours of lost generation			Hours of lost generation		
		Nkula (1)	Tedzani (2)	Kapichira (3)	Nkula (4)	Tedzani (5)	Kapichira (6)
1	Post	-342.049 (550.355)	-135.659 * (73.050)	-225.768 (139.128)	-25.974 (33.509)	-9.756 ** (4.616)	-50.762 (43.689)
2	Time	4.643 (3.823)	0.467 (0.644)	1.060 (1.018)	0.338 (0.240)	0.025 (0.050)	0.575 * (0.320)
3	Post x Time	-9.567 (9.033)	2.440 (1.892)	2.184 (3.015)	-0.704 (0.570)	0.177 (0.141)	-0.597 (0.683)
4	Precip (mm)	7.431 (6.702)	0.757 (0.822)	1.264 (1.631)	0.441 (0.396)	0.039 (0.043)	0.542 (0.538)
5	Lag 1 Precip (mm)	-0.963 (1.631)	-0.046 (0.280)	0.801 (0.662)	-0.034 (0.100)	-0.004 (0.018)	0.003 (0.134)
6	Constant	-437.798 (387.732)	-6.257 (57.613)	-105.586 (100.215)	-18.892 (17.992)	2.301 (2.949)	-32.584 (24.436)
7	Average treatment effect	-552.526	-81.987	-177.718	-41.462	-5.868	-63.895
8	Pre-treatment mean	354.790	77.711	117.322	26.374	6.038	34.344
9	Post-treatment mean	143.767 (*p* = 0.431)	30.044 (*p* = 0.195)	16.376 (*p* = 0.135)	9.687 (*p* = 0.303)	2.015 * (*p* = 0.078)	12.342 (*p* = 0.302)
10	R^2	0.078	0.058	0.090	0.084	0.053	0.079

Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: Robust standard errors are reported in parentheses. The *p*-values reported in row 8 are from a two sample t-test comparison of means between pre-treatment and post-treatment values. Each model includes contemporaneous and lagged monthly rainfall totals as measured at Liwonde using data from CHIRPS. We count June 2018 as the start of the "post" period, the first full month following the May 2018 delivery of weed-harvesting equipment. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Weed removal is reducing downstream impacts as intended. Staff at the Kapichira power station remarked that effective weed management at Liwonde means they no longer need to shut down the plant to remove weeds.

4. Sustainability of weed-removal activities

RQ 4. How do the power plants ensure appropriate maintenance and repair of the equipment provided under the WSM activity?

EGENCO engineers shared that the weed-harvesting equipment undergoes routine maintenance. Each day before a harvester begins operations, an operator checks equipment components. Routine maintenance procedures, such as servicing fuel filters, are conducted each time the equipment has been cumulatively operating for the prescribed duration. Marine surveyors also monitor equipment for seaworthiness before providing the equipment with the relevant certification.

Procuring spare parts, however, has been more challenging, because local suppliers do not stock the relevant items, such as conveyor meshes, and the procurement process involves several steps, each of which can cause delays. Spare parts, such as the conveyor meshes, conveyor motors, hydraulic pipes, and fuel filters are sourced from a U.S.-based supplier, and shipping delays can interrupt operations when a sufficient supply of spare parts is not stocked. For example, a purchase invoiced from July 2020 for several parts was not received until June 2021. One of the pre-MCC harvesters had been inoperable until that shipment, which included spare conveyor meshes, arrived. Although EGENCO staff have a checklist of spare parts to keep on hand, they note that *completing* the procurement process is subject to significant delays. It involves engineering staff submitting a budget request, awaiting budget approval, initiating procurement, then submitting a request to purchase. Government approval is often also required and might cause further delay.

"So, I think, what is required is for us to initiate it in good time. We shouldn't … wait until all the spares are depleted, we have to make sure that we restock before they completely get dried." (ES4)

RQ 5a. What are stakeholders' perceptions of the sustainability of outcomes of the [weed removal] WSM activity?

EGENCO singlehandedly determines whether weed-management activities will continue; interviewees point to the annual line-item budget for weeding expenditures as evidence this activity will be sustained, because it receives earmarked funding. Since EGENCO owns the equipment, employs the staff who operate it, and is the primary beneficiary of gains from effective weed management, it near-entirely determines whether the outcomes from this WSM Activity will be sustained. Interviewees from EGENCO and the company's sustainability plan (EGENCO 2018) stated that weed-removal activities at Liwonde will continue, and that the prerequisites for effective weeding, such as staff recruitment and training, spare parts purchases, equipment maintenance, and funding, will be assured. The strongest evidence for whether EGENCO will continue these activities comes from the amount budgeted for weed management. We note from documentation shared by EGENCO that from the July 2018–June 2019 operating year to present, they have an annual budget estimated for all Liwonde weed-management costs that includes charge categories that cover salaries, fuel for the water vessels, electricity, and approximately 65 other cost codes. We estimate that the year-on-year change in the nominal budget has been variable, from a high of 38 percent between 2018–2019 and 2019–2020, and a low of -9 percent between 2020–2021 and 2021–2022. Since annual consumer price inflation between 2011 and 2020 has averaged more than 16.5 percent, annual spending on weed management would have to grow at comparable levels to keep pace with inflation, assuming that sustaining outcomes will require at least a constant real amount.[16] Interviewees claimed that if problems grew more intense, EGENCO would be able to reallocate staff to increase equipment operating hours.

Stakeholders noted that routine equipment maintenance will be central to ensuring the sustainability of weed-removal benefits. If the equipment is not maintained and spare parts kept on hand, staff will be unable to achieve the weed-removal levels achieved in the past couple years. EGENCO technical staff and leaders indicated that procedures had been put in place to minimize shortages in spare parts and consequent equipment downtime. Failure to follow these procedures will undermine the power-generation gains from weed management.

[16] Consumer price inflation data is available through the World Bank's Open Data portal at https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?end=2020&locations=MW&start=1981&view=chart.

B. Sediment-removal / dredging activities

In this section, we report our key findings on the sediment dredging activities that have taken place at Kapichira, shown at the most downstream point of interest on the Shire River in Figure I.2. As parts of this activity were implemented only after the compact closed, we discuss implementation and deviations against the original plan in Section IV.B.1. We then examine dredging performance by analyzing equipment operating time and total dredging expenditures data in Section IV.B.2. In Section IV.B.3, we share the results of the ITS models to understand the impact of dredging operations on HPP productivity. Section IV.B.4 addresses the potential challenges to sustaining the gains made from Kapichira dredging.

1. Findings of post-compact implementation

RQ 1. How was the activity implemented?

RQ 1a. How did actual equipment purchased deviate from the original plan?

The initial procurement effort for purchasing dredging equipment, used to remove sediment that builds up in a reservoir and reduces a reservoir's active storage capacity, combined both the dredging and weeding equipment into a single request for bids (see Coen et al. 2019).[17] Because manufacturers produce either one type of equipment or the other, the effort encountered failures and delays. A key byproduct of those procurement efforts was that dredging equipment intended for Nkula was cancelled, and the dredging equipment for use at Kapichira was delayed in its delivery and initial operations.[18] As a result, we discuss equipment and operations only at Kapichira, because the high-capacity cutter suction dredger described in Fichtner (2014) was not procured. In contrast, the Kapichira HPP received the planned high-capacity dredger which was off-loaded right after the compact ended, along with two backhoes and two tipper trucks.

The dredging operations at Kapichira revolve around the newly acquired dredge, a Series 1270 Dragon Dredge manufactured by Ellicott Dredges. The dredge has two engines, an 800 horsepower (HP) Caterpillar C32 main engine, and an auxiliary 375 HP Caterpillar C9 engine. Several support boats also operate at the site, including a work boat, a survey boat, and a crew boat that transfers staff from the jetty to the dredge. The diesel-powered dredge has a capacity of 88,000 liters and is refueled by a delivery truck that returns to the site monthly. An approximately 1-km onshore pipeline transports sediment from the dredge to a disposal management placement area (DMPA), complemented by a slightly shorter floating pipeline (shown in Figure IV.9). Although the dredger is currently launched from a grassy jetty, EGENCO plans to improve this area into a docking bay for refueling, with offices and a dedicated repair area. EGENCO's dredging operations team consists of nine employees, including senior marine technicians, dredger operators, an intake attendant, and two tipper truck drivers.

[17] The JGH Group served as a middleman agency and responded to the bundled procurement request. The dredge portion of that contract was terminated and was the subject of a case study written by MCC's external counsel.

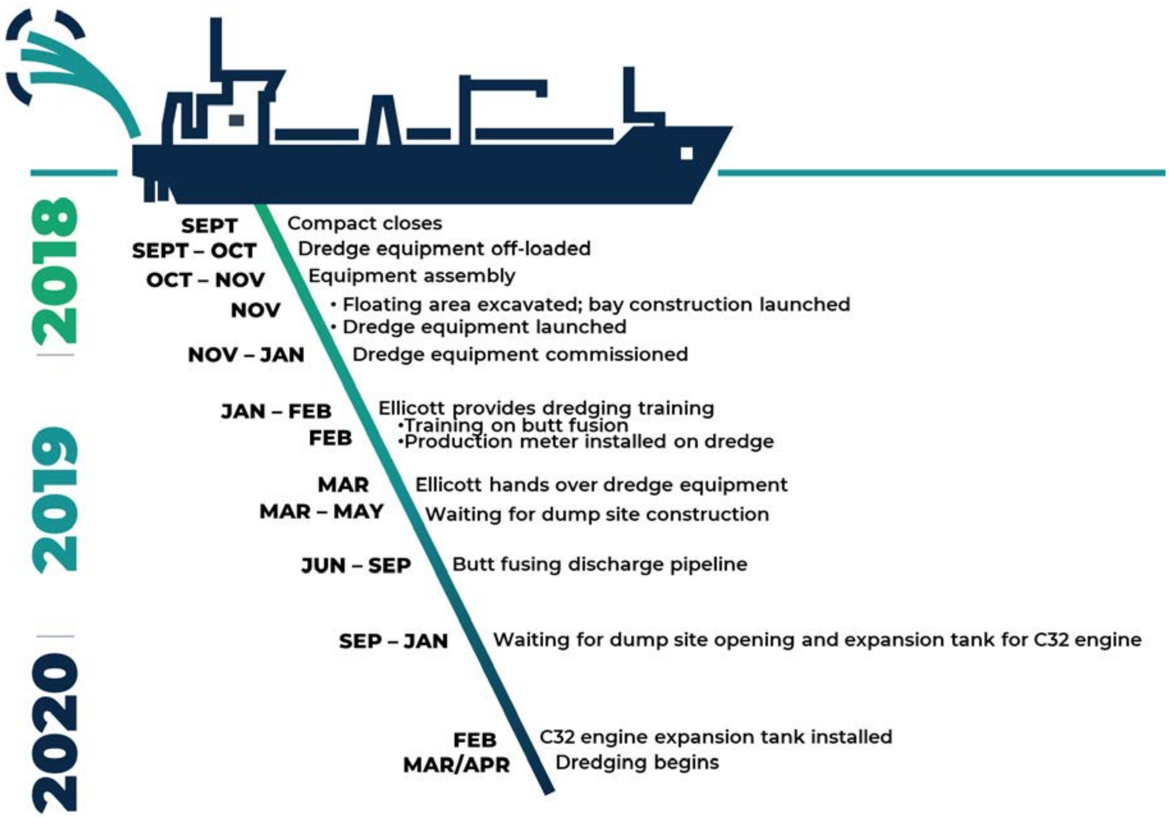
[18] One interviewee noted that the Kapichira dredge could be disassembled and operated at Nkula or Tedzani, but to the best of our understanding, EGENCO has not done this (MCC1).

Figure IV.9. Dredge at Kapichira connected to floating pipeline

EGENCO received the dredge shortly after the compact ended, but the dredge was not fully operational until April 2020, about 18 months after compact closure. Aside from procurement-caused delays, dredging began later than expected because of delays constructing the DMPA and modifications needed to adapt the dredge to Malawi's environmental conditions. The timeline shown in Figure IV.10 captures key milestones covering the period from when the dredge equipment was off-loaded through to when dredging began. Following the equipment off-loading, commissioning the dredge was completed early in 2019. Shortly after, the dredge manufacturer provided EGENCO staff with equipment operation and maintenance training. After the equipment was formally handed over to EGENCO in March 2019, operations were on hold for the next several months. During that time, the DMPA construction and the butt-fusion activities to construct a pipeline between the dredging site and the DMPA were undertaken.

In 2019, it became evident that the dredge needed technical modifications to operate properly. Some dredge engines fail in tropical conditions because of the adverse effect that heat and humidity have on computerized fuel pumps. While a booster unit to reduce overheating was included in an early stage of dredge design specifications, the delivered dredge ultimately did not include one. Even though it was well-recognized that the dredge face overheating problems, it is not entirely clear why the booster unit was removed from the final dredge design. As a result, vapor would build up in the C32 main engine expansion chambers of the delivered dredge and trigger coolant oil leaks. The latter part of 2019 was spent waiting for an expansion tank to arrive and for the DMPA to open. The expansion tank was installed in February 2020 and resolved the coolant leakage problem. Dredging at Kapichira began two months later, between late March and early April.

Figure IV.10. Event timeline for Kapichira dredging activities



Source: Created based on interviews with EGENCO technical staff

A key deviation from the implementation plan, as cited by EGENCO interviewees, was the substitution of a diesel-powered dredge for an electric dredge. EGENCO interviewees indicated that the diesel fuel required to power the dredge represented an additional and unexpected burden on EGENCO's finances, in contrast with using electricity produced by the Kapichira HPP that could have powered an electric dredge. Although Fichtner (2014) specified an 11-kilovolt electric cable to power the dredge, one interviewee stated that the substation needed to transform the plant output voltage to levels compatible with the dredge had never been budgeted in the compact. Hence, the diesel dredge model was procured.

> **"This other dredge, diesel dredge, it requires for us to purchase diesel…so it becomes quite expensive. …If we had the electrical dredger the power supply would have been supplied fast. I think that was the major concern on that, that we opted for an electrical one."**
>
> ***EGENCO staff (ES3)***

2. Performance of dredging activities

RQ 1b. Did the equipment actually purchased perform as expected in terms of the quantities of sediment dredged?

RQ 2. To what extent did the activity restore active storage at the hydropower plants during the compact and after it ended?

RQ 2a. How did implementation of the dredging operations and disposal compare to the sediment management strategy?

Before discussing the performance of the new dredge, it is important to note that two separate documents outline dredging plans for the Kapichira site, each with their respective assumptions about how much silt should be removed and the accompanying operational requirements. The first report was an engineering study MCA-Malawi commissioned to develop technical specifications for procuring a dredge and ancillary equipment to alleviate sediment-related HPP losses (Fichtner 2014). It informed a second report submitted as part of the compact closure process that outlines the procedures EGENCO intended to undertake to sustain WSM activities (EGENCO 2018).

As Table IV.3 shows, these two documents differ on sediment removal targets and operating schedules. For example, Fichtner (2014) provides a final target of adding 850,000 m^3 of storage capacity through sediment removal and claims this would achieve 3.1 million m^3 of reservoir storage upon the completion of capital dredging efforts, which is the period of more intensive dredging that would then be followed by routine maintenance dredging. EGENCO's plan aims to remove all sediment in the reservoir (6.3 million m^3) and unlike Fichtner (2014) does not differentiate between sediment in active versus inactive storage. Its 6.3 million m^3 target approximately doubles Fichtner's estimate of total sediment deposition. Whereas Fichtner (2014) reported reservoir storage capacity levels for both 2000 and 2013 to highlight the pace of sediment buildup, EGENCO only reports values for a snapshot (presumably 2018) which differ from Fichtner's.

Table IV.3. Comparison of Fichtner and EGENCO sediment management strategies for Kapichira reservoir

Dimension	Fichtner's "Sedimentation Design and Management Report"	EGENCO's "Commissioning and Sustainability Plan"
Reservoir characteristics		
Kapichira reservoir storage capacity	5.2 million m^3 (2000) 2.0 million m^3 (2013)	9.1 million m^3
Total sediment deposition	3.2 million m^3 (2013)	6.3 million m^3
Active storage capacity	3.4 million m^3 (2000) 1.0 million m^3 (2013)	Not reported
Total sediment deposition in active storage	2.4 million m^3 (2013)	Not reported
Baseline share of active storage lost to sediment depositions	71%	70%
Sediment volume reclamation target (during the capital dredging)	850,000 m^3	6.3 million m^3
Reservoir storage after capital dredging	3.1 million $m^{3\,@}$	9.1 million m^3

Table IV.3. ***(continued)***

Dimension	Fichtner's "Sedimentation Design and Management Report"	EGENCO's "Commissioning and Sustainability Plan"
Dredging operations		
Daily operating hours	8 hours/day	24 hours/day
Shifts per day	1	3
Operating cadence	5 days/week	7 days/week[#]
Capital dredging duration	4 years: Years 1-2: one dredger Years 3-4: two dredgers	2 years
Estimated removal rate during capital dredging[*]	Years 1-2: 308,000 m^3/year Years 3-4: 616,000 m^3/year	3.4 million m^3/year

Source: Fichtner (2014) and EGENCO (2018)

[@] This value is reported in Table 5-2 of Fichtner (2014) but does not appear to be consistent with other calculations disclosed in the same report.

[#] Plan does not indicate the number of days/week, but various interviewees independently told the evaluation team that dredging was intended to be performed 24/7.

[*] We apply Fichtner's annual re-sedimentation rate of 250,000 m^3 to both Fichtner's and EGENCO's calculations.

Differences between the reports' characterizations of reservoir conditions, coupled with competing **dredging operations parameters, mean the reports have very different implications for dredging rate targets and therefore the cumulative dredged amount.** Fichtner (2014) explicitly prescribed a four-year capital dredging period, the first two years during which the Kapichira dredge would operate in isolation, followed by another two years during which the intended Nkula dredge would relocate to Kapichira to double the dredging capacity. Assuming the two dredges shared common technical specifications, Fichtner (2014) estimated a combined removal rate of 616,000 m^3/year in those latter years. Since EGENCO (2018) set a substantially higher removal target—6.3 million m^3 of sediment—and half the capital dredging duration of Fichtner (2014), achieving its target would require meeting a removal level of 3.4 million m^3/year.[19]

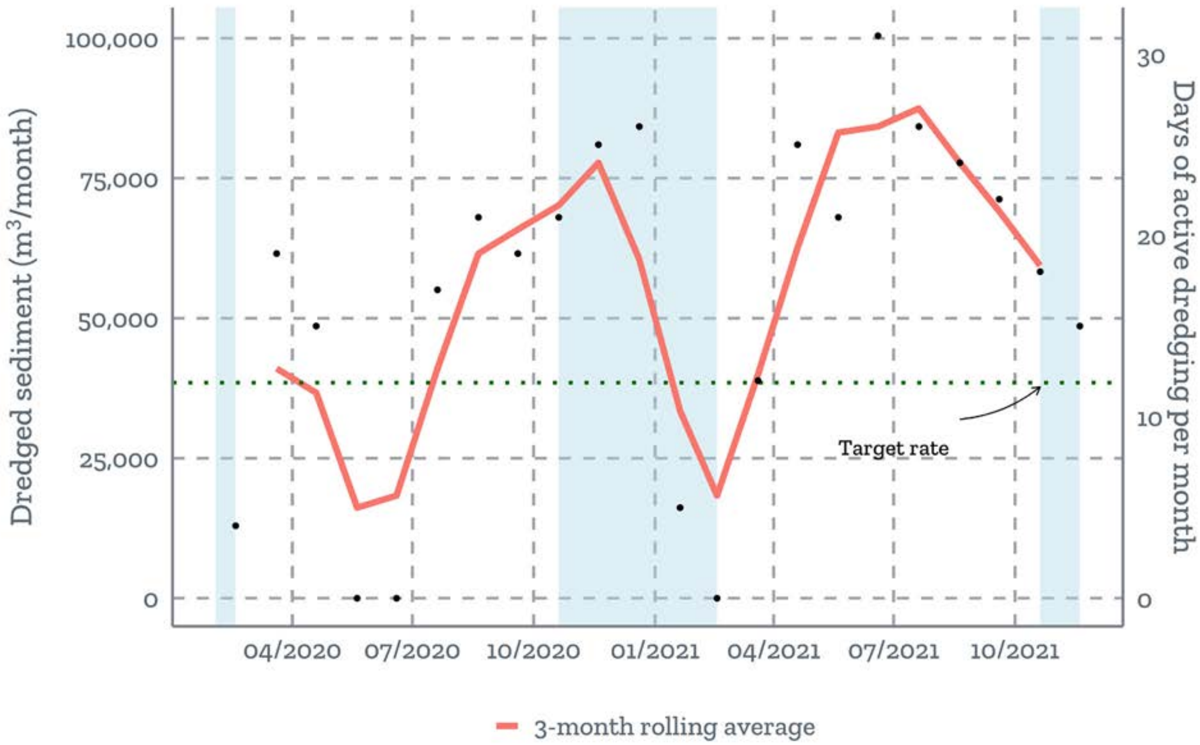
Dredging operations at Kapichira from April 2020 to date have exceeded the targets described in Fichtner (2014). Over this period, approximately 1.17 million m^3 of sediment has been removed, translating to an average rate of 55,800 m^3 monthly.[20] Although the total dredging period to date is not long enough to support reliable comparisons over time, the data indicates that dredging performance has increased over time. For example, 729,000 m^3 was dredged in 2021, whereas over the earlier one-year period of April 2020 to March 2021, a comparatively smaller total of 544,000 m^3 was dredged. Over the 21-month period for which data is available, performance has exceeded the monthly rate even under the higher 616,000 m^3/year target in Fichtner (2014) for Years 3 and 4 of the capital dredging plan (51,300 m^3/month), as seen in Figure IV.11. Even after accounting for re-sedimentation, since the reservoir is continuously accumulating sediment deposits from upstream sources regardless of the intensity of dredging activity, the data indicates that EGENCO's performance to date would mean that dredging activity should shift into a maintenance mode. Relative to EGENCO's own plans, however, cumulative

[19] Although the four years that separate the two reports' publication dates could account for some of differences in reported values, we control for ongoing re-sedimentation by using the 250,000 m^3/year estimate in Fichtner (2014) to adjust the EGENCO estimates under a shorter capital dredging period.

[20] EGENCO's estimates for dredged sediment volumes are based on assuming an average dredging rate of 270 m^3 for each hour of operation, under an average 12 hours of operation per day, multiplied by the number of days the dredge operates in a given month. As a result, the monthly dredged volume is a scale factor of the number of operating days.

dredging has removed only 19 percent of the target reclamation volume of 6.3 million m^3 and does not come close to achieving the associated removal rate of 3.4 million m^3/year.[21]

Figure IV.11. Kapichira dredge activity and sediment removal volumes by month



Source: Mathematica calculations using data from EGENCO.

Note: Light blue bars denote when observations fall within the rainy season which spans November through March. The target rate of 38,500 m^3/month of sediment removed is based on Fichtner (2014) estimates that would achieve an 850,000 m^3 reduction of sediment deposition in the Kapichira reservoir over four years. Monthly dredged sediment is a scale factor of the number of active dredging days, based on an assumed hourly removal rate of 270 m^3, for an average of 12 hours per day. For this reason, the left vertical axis is perfectly correlated with the right vertical axis at a 270:1 ratio. N = 22 monthly observations for March 2020 through December 2021.

EGENCO's sustainability target assumed 24/7 operations, but actual operations are substantially lower. We estimate that the dredger has been active for 57 percent of the days since dredging activities began in earnest in April 2020.[22] EGENCO's capital dredging plan had assumed three shifts of 8 hours each per day (EGENCO 2018, Section 3.3.5.iii), but actual operations occur in a single 12-hour shift. EGENCO interviewees shared that the dredge's diesel engine requires downtime to cool off, which mechanically imposes a limit on how much dredging can be performed each day. Three of the months since April 2020 saw complete dredging shutdowns because of mechanical issues. A clutch problem affected operations in June and July 2020, when operations were shut down in March 2021 while a

[21] We note that Tropical Cyclone Ana, which made landfall in Malawi on January 24, 2021, resulted in damage to the dredging infrastructure at Kapichira. The pipeline broke loose from its moors, but we do not know the extent of damage to the dredge itself. As a result of Ana, the Kapichira HPP lost about 130 MW of production, as per https://www.voanews.com/a/malawi-loses-30-of-its-electricity-to-tropical-storm-ana-/6429686.html.

[22] This value is based on dredging data provided by EGENCO and covers April 2020 through December 2021.

contractor performed maintenance services. Only in July 2021 did the number of active dredging days exceed 30.

One factor for the discrepancy between actual dredged volumes and EGENCO's forecast is that the sustainability plan overestimated the dredging rate efficiency. EGENCO assumed the dredge could remove 360 m^3 of sediment per hour. If operated continuously for two years, that rate would achieve the reclamation target. However, dredge operators have realized that actual performance is 25 percent less efficient than assumed and are observing estimated dredging rates of 270 m^3 per hour.

Sediment disposal in practice has not followed the sediment management plan of releasing rainy season dredged sediment downstream and only disposing dry season sediment in the DMPA. Fichtner (2014) envisioned that sediment disposal methods would vary by season. During the rainy season, sediment could be released downstream into the Shire River and would continue to flow on into the Zambezi River and empty into the Mozambique Channel. Although some unintended impacts from this practice were anticipated, the presumption was that river flow rates swollen by the rains would in essence dilute the sediment to acceptable concentrations. Removing sediment in this manner would limit demand for on-land sediment disposal at DMPA to only dry season months, thereby extending the operational life of the DMPA (shown in Figure IV.12). In actuality, nearly all reclaimed sediment has been disposed of in the DMPA, and very little has been removed through downstream releases. One EGENCO interviewee stated that questions and complaints from downstream stakeholders prompted EGENCO to cut back the rainy season-specific sediment management practice, causing EGENCO to shift exclusively, or near-exclusively, to DMPA disposal.

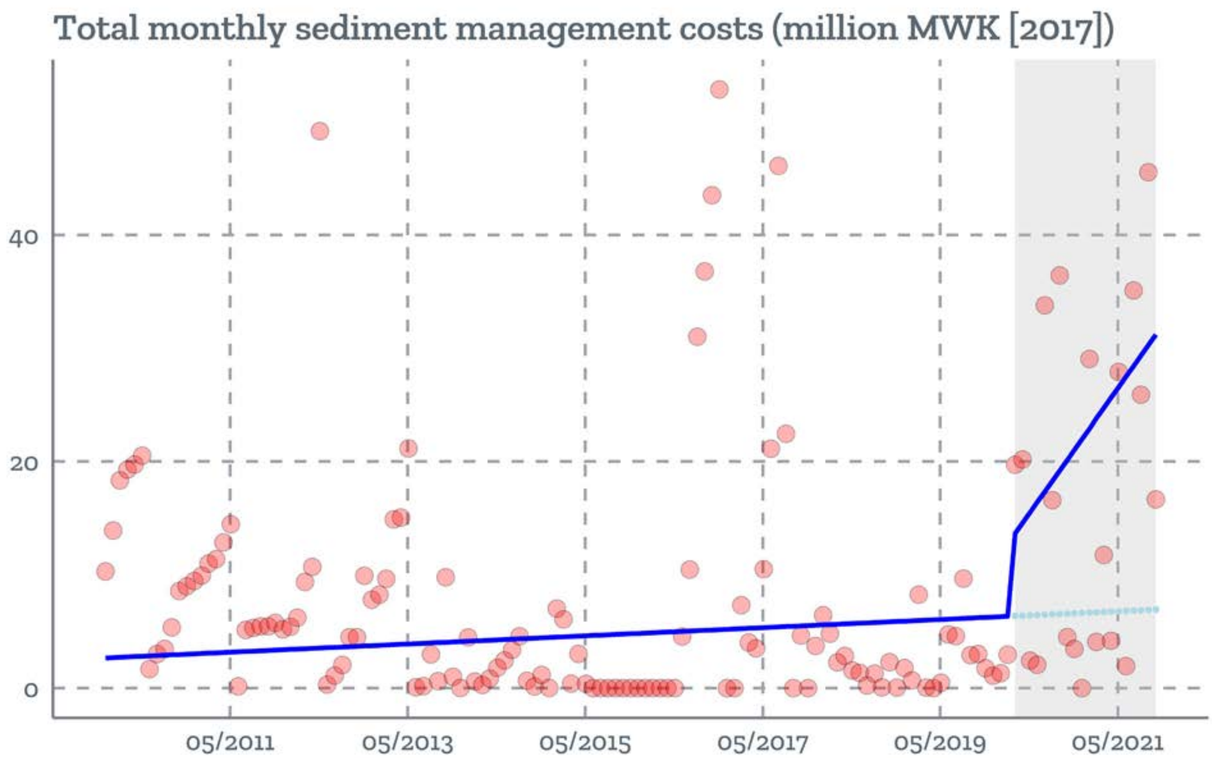
Although sediment removal practices tailored to each season would not necessarily translate to seasonal *dredging* patterns, we do not see strong evidence for any difference in dredging intensity between the rainy season and the non-rainy season, as displayed in Figure IV.11. The November–March rainy season is denoted by the vertical blue rectangles, and maximum dredging activity levels in those months is comparable to maximum levels achieved during the remaining months of the year.

The DMPA consists of two pits, one already filled to capacity and the other approaching its capacity. The already filled smaller pit has a capacity of 250,000 tons with a depth of 9 meters, while the larger pit is 12 meters deep with a 350,000-ton capacity. EGENCO interviewees had assumed that local farmers would remove and use the sediment, which they claim is fertile and suitable for agriculture, but demand for the sediment has been restricted to usage in small market gardens and therefore not an effective curb to DMPA accumulation. Kapichira site staff stated that the local communities could be sensitized to the sediment's agronomic value. EGENCO is simultaneously partnering with a local university to explore alternative silt uses, such as packaging it for soil stabilization.

Figure IV.12. Sediment accumulation at the Kapichira DMPA

EGENCO's monthly expenditure on sediment management increased by an average of 15.8 million MWK (2017) [USD 21,641] after the Kapichira dredge began operating. No pre-treatment data on Kapichira dredging expenditures are available because there was no dredging until the dredge arrived. As a result, Kapichira dredging costs cannot be analyzed in isolation using the ITS approach. However, by combining dredging costs for Nkula and Kapichira, we can test whether EGENCO in fact increased its total dredging management costs, or whether efforts at Nkula were downsized to keep total dredging costs across the two sites constant over time. Total monthly spending on sediment management increased substantially once the Kapichira dredge began operating (Figure IV.13). Whereas EGENCO was spending a monthly average of 4.4 million MWK (2017) on dredging in Nkula before the Kapichira dredge arrived (Table IV.4, Row 8), monthly expenditures increased sharply to more than 22.6 million MWK (2017) after its arrival (Row 9). In the pre-treatment period, average month-on-month growth was 30,000 MWK (Table IV.4, Row 2), which increased significantly to more than 890,000 MWK (Row 3) after April 2020. The average increase in monthly expenditure of 15.8 million MWK (Table IV.4, Row 7), is the mean difference between the solid blue line, which represents the fitted actual values, and the dotted light blue line, which represents the counterfactual trend had no Kapichira dredge been provided.

Figure IV.13. ITS results for monthly sediment management costs combined across Nkula and Kapichira



Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: The gray rectangle denotes the post-treatment period, which starts in April 2020, the first full month of operations using the MCC-funded sediment removal equipment. The dark blue line depicts the fitted results from the main ITS specification, holding contemporaneous and lagged monthly precipitation at sample mean values. All regression models include a trend term, a post indicator to denote the post-treatment period, an interaction of the trend term and the post indicator, and contemporaneous and lagged rainfall as measured at Liwonde. N = 143 monthly observations for January 2010 through November 2021.

Table IV.4. Regression results for ITS model of sediment management costs

Row #	Variable	Monthly expenditure on sediment management (Nkula and Kapichira) [million 2017 MWK] (1)
1	Post	6.400 (7.834)
2	Time	0.030 * (0.016)
3	Post x Time	0.893 (0.700)
4	Precip (mm)	-0.015 (0.010)
5	Lag 1 Precip (mm)	-0.004 (0.010)
6	Constant	3.370 *** (1.040)
7	Average treatment effect	15.780
8	Pre-treatment mean	4.409
9	Post-treatment mean	22.644 *** (*p* < 0.001)
10	N	143
11	R^2	0.326

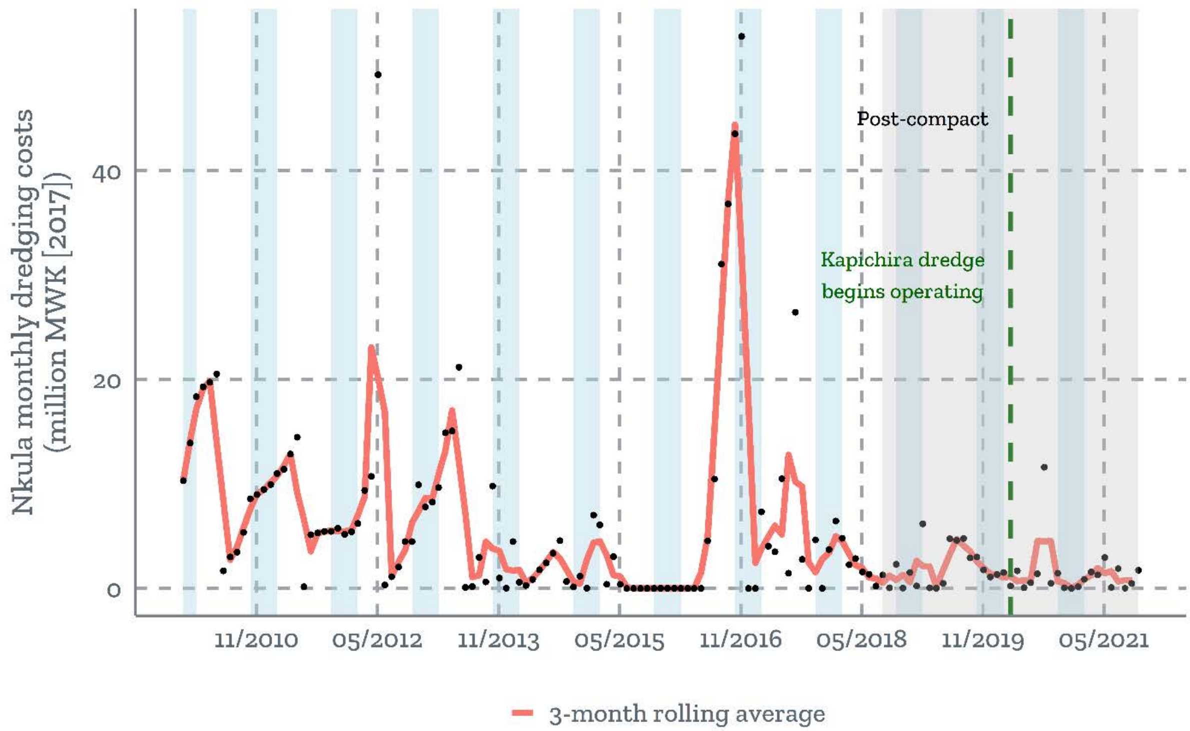
Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: Robust standard errors are reported in parentheses. The *p*-value reported in row 9 is from a two sample t-test comparison of means between pre-treatment and post-treatment values. Each model includes contemporaneous and lagged monthly rainfall totals as measured at Liwonde using data from CHIRPS. We count April 2020 as the start of the "post" period, as the first full month following the March 2020 initial operation of the Kapichira dredge. We calculate constant 2017 MWK using the annual GDP deflator series available through the World Bank World Development Indicators and linearly interpolating at the monthly level. The MWK:USD exchange rate for July 1, 2017 was 730.1:1, as per https://www.xe.com/currencytables/?from=MWK&date=2017-07-01#table-section. N = 143 monthly observations for January 2010 through November 2021.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Despite spending more per month in combined total dredging costs at Nkula and Kapichira, dredging expenditures at Nkula have shrunk since the compact ended. Nkula dredging has been seasonal, with spikes tending to occur either during the rainy season (blue vertical bars) or immediately following (Figure IV.14). Those peak values have gradually diminished over time, with month-to-month variability since 2018 substantially lower than in previous years. Part of the observed reduction in operating costs is likely due to the deteriorating state of the Nkula backhoe dredge and the Nkula DMPA reaching its life expectancy. Combined with the results of Figure IV.13, dredging at Kapichira has represented a real cost increase to EGENCO and not just a reallocation of costs from one site to another.

Figure IV.14. EGENCO's monthly sediment management costs at Nkula (in million 2017 MWK)



Source: Mathematica calculations using data from EGENCO.

Note: Vertical light blue bars denote the rainy season which spans November through February. The dredging equipment at Kapichira was considered fully delivered to EGENCO as of April 2020. The compact formally closed in September 2018, and the gray box denotes the post-compact period.

3. Impacts of dredging activities on electricity generation

The following results are based on the performance of the dredger that has been operating in Kapichira, because the compact did not provide the anticipated dredger at Nkula.

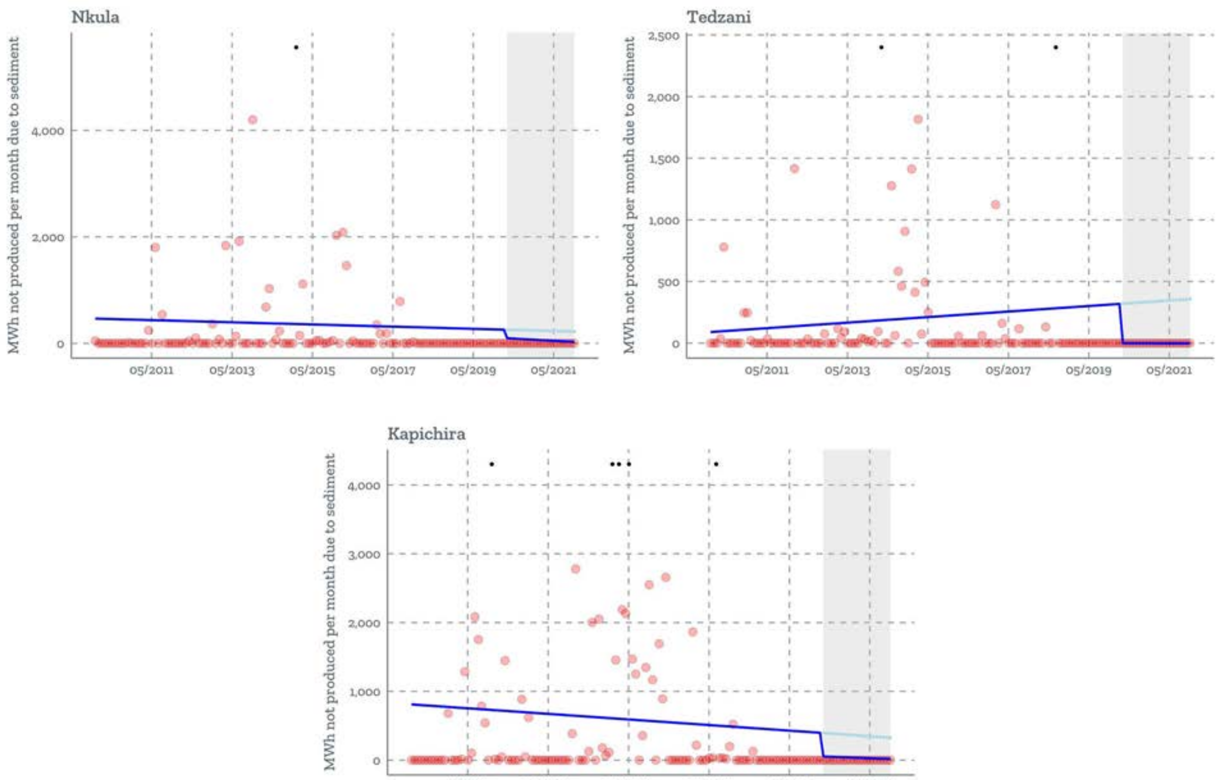
RQ 3. Did the new dredger affect power plant operations and power generation after the compact ended?

RQ 3b. How did the use of actually purchased equipment and related improvements vary by hydropower plant?

Analogous to our earlier ITS models examining the impacts of the weed-harvesting equipment, in each of the following models, we construct the treatment period as beginning in April 2020, which is the first full month in which the compact-funded dredging equipment was operating at Kapichira. Our empirical approach consequently marks that month as the start of the *treatment* (the "post" period), for all specifications examining the impacts of Kapichira dredging on electricity outcomes.

Across each of the three HPPs, the amount of electricity that was not produced because of sediment-related causes dropped to zero in the post-treatment period (Figure IV.15)**.** Since consecutive months registering no generation losses also occurred in 2018 and 2019, before the Kapichira dredge became operational, we posit that factors other than MCC's investments contributed to these HPP productivity improvements. Furthermore, dredging activities at Kapichira, the most downstream HPP, would have no direct effect on operations at the upstream Nkula and Tedzani HPPs, yet we observe improvements at those two HPPs. One EGENCO interviewee shared that silt-related losses depend on water flows, and that improvements in water quality can reduce blockages. As a result, the observed absence of sediment-caused losses is due not only to dredging, but also to improvements in Shire River water flow that are independent of dredging activities. Both Nkula and Kapichira HPPs have downward-sloping pre-trends (dark blue) due to the relatively sparse number of months in the last two years of the pre-treatment period (that is, May 2018 through May 2020), which saw any sediment-caused losses in megawatt-hours generated. Given that the dredging work was designed to benefit electricity production at the Kapichira plant, it is unsurprising that the largest difference in mean monthly production losses from silt, from 613 MWh before dredging to 0 MWh afterwards, occurred at Kapichira (Table IV.5, Rows 8 and 9).

Figure IV.15. ITS results for megawatt-hours of electricity not produced per month due to sediment, by hydropower plant

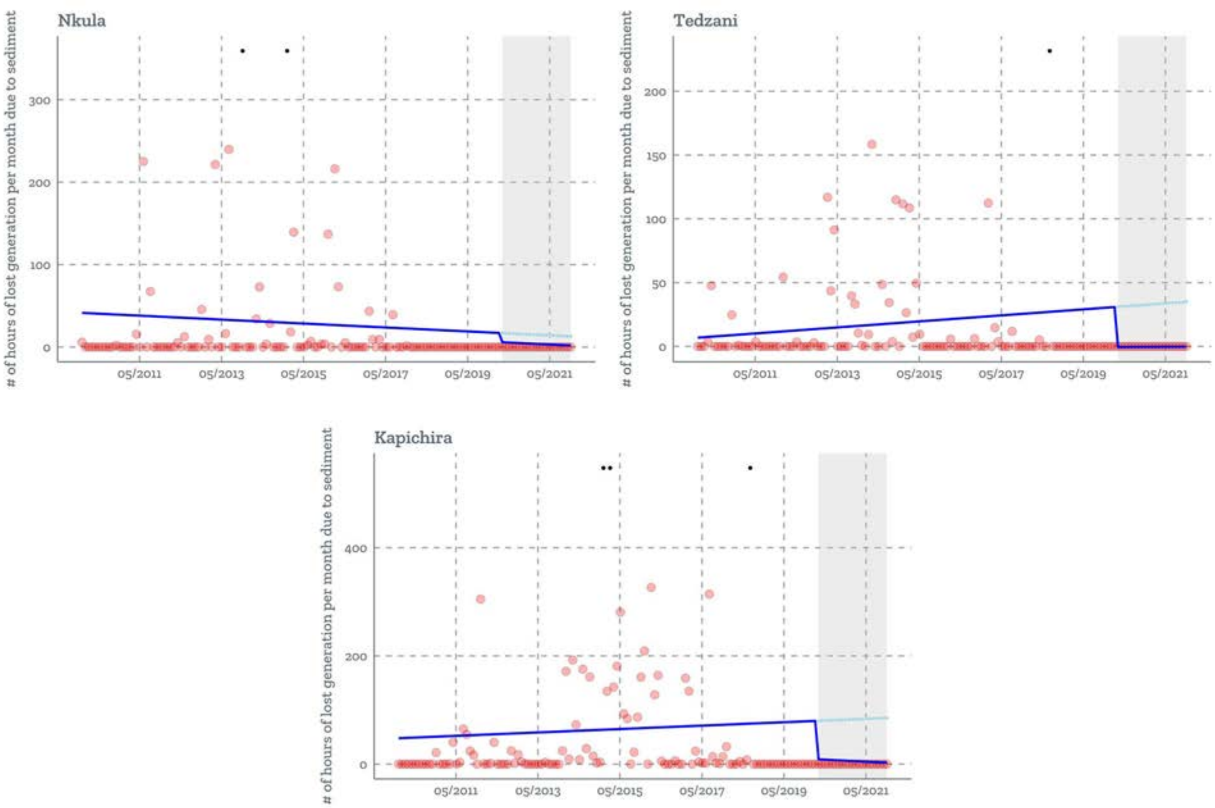


Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: The gray rectangle denotes the post-treatment period, which starts in April 2020, the first full month of operations using the MCC-funded sediment removal equipment. Outlier values that are two or more standard deviations from the sample mean value for that HPP are displayed in black for improved interpretability. The dark blue line depicts the fitted results from the main ITS specification, holding contemporaneous and lagged monthly precipitation at sample mean values. All regression models include a trend term, a post indicator to denote the post-treatment period, an interaction of the trend term and the post indicator, and contemporaneous and lagged rainfall as measured at Liwonde. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021.

The total plant downtime that HPPs experienced, measured as the number of hours for which turbines were not operating explicitly because of silt-related causes, also dropped to an average of zero hours per month in the post-period (Figure IV.16). Kapichira registered the largest stepwise decrease associated with treatment, at an average of 71 hours/month (Table IV.5, row 1). While Nkula's pre-treatment trend is negative, indicating that HPP downtime was already on the decline even before the Kapichira dredging began, pre-trends for Tedzani and Kapichira are positive and influenced by large losses in the latter portion of the pre-treatment period. Ignoring the role that rainfall plays in sediment-induced downtime, Kapichira, on this measure as well, registered the largest decline in mean monthly losses between and the pre- and post-periods at 65 hours/month (Table IV.5, row 8). That value is more than double the estimate at Nkula and supports the case for having prioritized Kapichira to receive new dredging equipment.

Figure IV.16. ITS results for hours of hydropower plant production lost per month due to sediment, by hydropower plant



Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: The gray rectangle denotes the post-treatment period, which starts in April 2020, the first full month of operations using the MCC-funded sediment removal equipment. Outlier values that are two or more standard deviations from the sample mean value for that HPP are displayed in black for improved interpretability. The dark blue line depicts the fitted results from the main ITS specification, holding contemporaneous and lagged monthly precipitation at sample mean values. All regression models include a trend term, a post indicator to denote the post-treatment period, an interaction of the trend term and the post indicator, and contemporaneous and lagged rainfall as measured at Liwonde. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021.

Table IV.5. Regression results for ITS models of sediment-induced HPP losses

Row #	Variable	Megawatt-hours of lost generation Nkula (1)	Megawatt-hours of lost generation Tedzani (2)	Megawatt-hours of lost generation Kapichira (3)	Hours of lost generation Nkula (4)	Hours of lost generation Tedzani (5)	Hours of lost generation Kapichira (6)
1	Post	-157.669 (202.386)	-319.226 (265.054)	-342.829 (233.164)	-11.122 (12.814)	-31.371 (26.388)	-70.649 ** (33.220)
2	Time	-1.699 (1.980)	1.872 (2.785)	-3.381 (3.242)	-0.199 (0.151)	0.197 (0.276)	0.262 (0.339)
3	Post x Time	-1.804 (9.160)	-1.905 (2.512)	1.520 (6.269)	-0.001 (0.563)	-0.181 (0.246)	-0.575 (0.764)
4	Precip (mm)	6.642 (6.526)	-0.853 (0.854)	4.917 (4.471)	0.417 (0.391)	-0.076 (0.079)	0.460 (0.488)
5	Lag 1 Precip (mm)	-1.409 (1.672)	0.709 (0.590)	-1.843 (2.663)	-0.109 (0.117)	0.043 (0.035)	-0.021 (0.160)
6	Constant	151.380 (215.659)	53.256 (127.939)	686.233 *** (255.235)	20.507 (15.304)	8.901 (6.291)	17.252 (17.371)
7	Average treatment effect	-177.515	-340.185	-326.111	-11.137	-33.364	-76.972
8	Pre-treatment mean	377.262	204.805	612.776	29.977	18.786	64.826
9	Post-treatment mean	0.000 * (*p* = 0.067)	0.000 ** (*p* = 0.020)	0.000 *** (*p* < 0.001)	0.00** (*p* = 0.023)	0.000** (*p* = 0.027)	0.000*** (*p* < 0.001)
10	N	144	144	144	144	144	144
11	R^2	0.059	0.016	0.075	0.058	0.015	0.052

Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: Robust standard errors are reported in parentheses. The *p*-values reported in row 9 are from two sample t-test comparison of means between pre-treatment and post-treatment values. Each model includes contemporaneous and lagged monthly rainfall totals as measured at Liwonde using data from CHIRPS. We count April 2020 as the start of the "post" period, the first full month following the March 2020 initial operation of the Kapichira dredge. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

4. Sustainability of dredging activities

RQ 5b. What are stakeholders' perceptions of the sustainability of outcomes of the [dredging] WSM activity?

> **"As we make our budgets this [dredger] is part of the equipment that we consider key to our operations and therefore budgets are provided for their maintenance and operations."**
>
> ***—EGENCO Staff (ES2)***

Similar to their weed-management efforts at Liwonde, EGENCO keeps a line item in its annual budget to fund dredging activities. The continuation of those funds is likely the most important determinant to sustaining the HPP productivity gains from dredging. Because the dredge has been operating for less than two years, it is too early to tell whether the funding earmarked for equipment maintenance, as parts age and require replacement, will be enough to keep the dredge operating at the intensity observed thus far. To increase the cost-effectiveness of dredge operations, EGENCO has requested a waiver of the diesel taxes paid from the treasury. EGENCO submitted this request on the grounds that the dredging activity produces a public good of greater supply and stability of electricity. But after nearly a year, it has yet to receive a response. Although the evaluation team assumes that dredging operations are profitable, when comparing operating costs against increased electricity generation, a diesel tax waiver would only further increase the likelihood that gains from dredging would be sustained by bolstering the case for continued dredging.

Sustaining the dredge's continued operation requires that spare parts be continuously well-stocked and equipment properly maintained. Equipment downtime is a key threat to the dredging operations and is a material concern given that several components lack local suppliers who can sell replacement parts. For example, the survey boat has a Honda engine, but there are no Honda dealers in Malawi. The work boat has John Deere engines, but the John Deere dealer in Malawi does not support marine diesel engines. EGENCO has had positive experiences in sourcing parts from a South African company, but delays may occur in receiving shipments from them. As discussed earlier, equipment malfunctions have already grounded the dredge for three months since April 2020, highlighting the essential role that availability of spare parts and routine maintenance procedures to minimize the need for emergency repairs will play in maintaining dredging performance.

> **"We are linking up with government to bring in…surveying specialists to survey the area that we have cleared out to construct another deposition section."**
>
> ***—EGENCO staff (ES5)***

As the DMPA fills its primary pit, new plans will need to be implemented to handle dumped sediment. Without effective ways to market the sediment and to find users who will take it from the DMPA, EGENCO will have to pursue the development of a new disposal site. Some interviewees mentioned that disposal demand would be reduced if land use practices throughout the Shire River Basin were improved, but as we discuss in Chapter V, there are no active efforts to ensure this happens. As a result, as long as EGENCO adheres to its plan of continuing capital dredging for some time, the existing DMPA will run out of space and hamper dredger operations unless another disposal site is available at that time.

C. Fidelity of WSM Activity to logic model

The program logic's characterization of how the WSM Activity is situated within the ENRM Project and the ultimate compact goal of poverty reduction and economic growth is accurate. The model assumes that weed management and dredging activities are independent of the other Project components, and in fact, they have been. We therefore do not believe that connections should be added to the existing model. The only change to the WSM Activity characterization that we would suggest is to make explicit that routine maintenance procedures and funds for ensuring the availability of spare parts should also be considered as a logic model input. Although this item is likely implicit within the text of "purchase and use of mechanical equipment," separating it makes clear that both outputs (for example, "improved control of aquatic weeds and sedimentation") and outcomes would not be achievable without a commitment to maintaining equipment.

V. FINDINGS FROM THE ENVIRONMENTAL TRUST EVALUATION

Summary of key findings

Implementation

- The Malawi Energy Regulatory Authority approved an electricity tariff increase in 2018 that in principle would have provided Shire Basin Environmental Support Trust (Shire BEST) with funding from Electricity Generation Company Malawi Limited (EGENCO) and Electricity Supply Corporation of Malawi (ESCOM) through an environmental management levy. However, that funding stream never materialized, and stakeholders offered different explanations for why.
- In lieu of disbursing levy funds, EGENCO since 2019 has signed two memoranda of understanding (MOUs) with Shire BEST that specify substantially lower levels of financial support than the annual $700,000 to $1.5 million range envisioned from the levy. For example, actual funds received in fiscal year 2019/2020 totaled 135 million MWK ($186,000), which was 27 percent of MCC's disbursement target for 2019.

Results

- The trust has supported one implementing partner, Training Support for Partners (TSP). But it had to terminate TSP's contract after six months because Shire BEST lacked the funds to continue support. Instead, the funds remaining from the MOUs were repurposed to cover Shire BEST's operating costs.

Sustainability

- Securing a stable source of funding is the trust's paramount concern for achieving sustainability. At the time of data collection, Shire BEST did not have funding to support operations beyond March 2022.
- The trust continues to be well-positioned with respect to having key stakeholders from Malawi's energy and water sectors on its board of trustees.

The Shire Basin Environmental Support Trust (Shire BEST) was established to provide implementing partners with funds to carry out restoration activities in the Shire River Basin (Shire BEST 2018). Those activities would align with ENRM objectives, and if successful at scale, they would address needs for weed and sediment management in the basin. This chapter answers the following research questions about the implementation, results, and sustainability of the environmental trust:

1. What implementation factors supported or hindered the establishment of the trust?
2. To what extent is the trust on track to reach administrative, operational, and financial sustainability?
    a. Did the trust establish a funding mechanism, such as payment for ecosystems services (PES), and obtain sufficient capital to sustain grant investments beyond the life of the compact? Is trust funding at originally planned or expected levels? Why or why not?
    b. What is the trust's fundraising strategy to achieve sustainable financing over the long term? How was it developed?

The findings we present in this chapter are based on interviews with Shire BEST staff and trustees, interviews with Malawi Millennium Development Trust (MMD) and MCC staff, and a review of documents shared by Shire BEST, including audited financial statements, meeting minutes, and the most current version of the organization's strategy (Shire BEST 2018). We begin by summarizing the trust's administrative, operational, and financial achievements since September 2018, then describe the key sustainability challenges and concerns. In Section V.B we identify the most important factors affecting Shire BEST's ability to complete the steps involved in establishing an environmental trust, which had not been achieved at the time of our interim evaluation. We close in Section V.C by revisiting the ENRM Project theory of change to assess the fidelity of the trust's activities and effects against the program logic. Whereas this analysis focuses on developments and outcomes from the end of the compact to the present day, Coen et al. (2019) provide a complete description of the trust's implementation experience from its inception through the compact close.

A. Sustainability of environmental trust activities

RQ 2. To what extent is the trust on track to reach administrative, operational, and financial sustainability?

RQ 2a. Did the trust establish a funding mechanism, such as payment for ecosystems services, and obtain sufficient capital to sustain grant investments beyond the life of the compact? Is trust funding at originally planned or expected levels? Why or why not?

The trust has a functioning governance system comprising a secretariat and a board of trustees. The secretariat consists of two permanent staff: (1) a chief executive officer (CEO), who stepped into the CEO role in July 2019 after serving as a trustee, and (2) a finance and administration officer who joined at the end of 2019. Although the trust's strategy document did not specify a target headcount for the secretariat, noting that plans would be revised in accordance with actualized funding levels, the trust's organizational chart envisioned a secretariat with six distinct staff areas: (1) technical programs, (2) monitoring and evaluation, (3) finances and procurement, (4) administration, (5) fundraising, and (6) communications and outreach. Secretariat staff stated that in the absence of more staff members, they have been responsible for all tasks in those staff areas.

A board of nine trustees supports the secretariat. (All seats are filled.) The board has one chairperson, and trustees are also members of subcommittees, each vested with distinct leadership and oversight responsibilities. The three subcommittees—Finance and Administration, Investment and Fundraising, and Sustainable Environment and Natural Resource Management—meet quarterly, and each consists of four trustees, with one serving as the subcommittee chairperson. Only one trustee sits on two subcommittees; all others are on only one subcommittee. Although there are absences from subcommittee and board meetings, enough trustees are usually present to satisfy a quorum and proceed with meeting tasks.

Many of the most important organizations in Malawi's energy and water sectors have members on Shire BEST's board of trustees. Trustees include representatives from many of the key stakeholders in the area, including Electricity Generation Company Malawi Limited (EGENCO), Electricity Supply Corporation of Malawi (ESCOM), Malawi Energy Regulatory Authority (MERA), Illovo, PressCane, African Parks, the National Water Resource Authority (NWRA), and Mulanje Mountain Conservation Trust. These are organizations with direct insight into the role that Shire BEST can play in their operations, either by improving water quality and availability or having positive impacts on electricity supply and stability. As a result, these stakeholders share the trust's objectives. Their board membership continues to create two-way conversations about opportunities for Shire BEST to carry out its work, and for those organizations to partner with the trust. Because organizations are represented by specific office holders on the board, usually their CEO, turnover in organizational leadership would result in new board members filling those seats. Interviewees did not indicate that turnover has prevented the board from doing its work and supporting trust staff.

Coen et al. (2019) describe various funding mechanisms considered for capitalizing the trust, including an endowment, a PES model in conjunction with key Shire River Basin stakeholders, and local and international donor funds. Deliberations on which model to advance delayed the process of operationalizing one. An endowment model option, in which MCC would inject seed capital for the trust to manage and disburse grants from, was eventually shelved when MCC's legal counsel raised concerns that an endowment could be perceived as skirting the organization's five-year compact limit. At compact close, it had appeared the trust would use a PES mechanism in which major water users, such as utilities, water boards, irrigation users, industry, and hospital services, would fund Shire BEST to carry out ecosystem restoration services throughout the Shire River Basin. After plans to operationalize a PES model did not pan out, attention shifted to another funding option, by which a share of electricity bill payments could fund Shire BEST. MERA approved an increase in the environmental management levy imposed on electricity bills as part of the country's regular electricity tariff revision process.

Funds from that levy, collected by ESCOM (the country's power transmission and distribution company) and EGENCO could have been directed to Shire BEST. During the compact, ESCOM, EGENCO, MCC, MCA-Malawi, and Shire BEST had several conversations on this topic, because ESCOM and EGENCO would be the direct beneficiaries of any successes had by Shire BEST reducing soil and nutrient erosion in the basin. Since EGENCO stood to benefit more directly from any successes from Shire BEST, they would have been responsible for 75 percent of funds given to the trust and ESCOM responsible for the remainder. To aid ESCOM and EGENCO, which were preparing to submit a tariff revision to MERA, Shire BEST and MCA-Malawi sent a proposal to EGENCO outlining three funding-level options and what Shire BEST would be able to achieve under each. The "low scenario" presumed annual funding of $700,000 for five years and was described as "the minimum required to secure operations of the Trust and attain some field results" (Shire BEST 2018). The "medium" and "high" scenarios, respectively, involved $1.1 million and $1.6 million in annual support, with the high scenario enabling "increase[d] field-based investments … more sophisticated data and financial analysis, and … the option for significant scaling up of impact in later years" (Shire BEST 2018). Although MCC/MCA-Malawi did not ever see the actual budget submitted to MERA, one interviewee stated that when pressed on the matter, ESCOM and EGENCO claimed they submitted a line item for supporting Shire BEST at $700,000 per year, the low

"The idea of setting up Shire BEST was a good idea. All the groundwork was done. Very good documentation was there. The only thing that did not happen was to put what was discussed on paper and have Shire BEST to draw out with some funding. You don't just set up something and leave it without funding. How do you expect such an institution to run? So, if only the endowment was set up for Shire BEST, if only the electricity levy agreement was signed, I think that could have [better] helped Shire BEST begin its operation on a sound footing than the way it was done." (BM2)

scenario among the three proposed by the trust.[23]

Funding from the proposed electricity tariff levy never materialized, and stakeholders provided different hypotheses for why. Our stakeholder interviews revealed that there was no discrete event or action to explain why Shire BEST did not receive funding from the tariff levy at the levels discussed during the compact. One explanation is that there never was a legally enforceable agreement between Shire BEST and EGENCO, despite MERA's approval of the levy; instead, one interviewee stated that the "agreement" was a nonbinding, verbal arrangement with the aspiration of entering into a contract that was never formalized. The absence of a written contract committing funds to Shire BEST corroborates this claim. EGENCO's 2018 application for a tariff adjustment, for example, did not explicitly identify Shire BEST as the intended recipient of any levy funds. Because the tariff request was submitted after the compact closed, MCA lacked the staff to follow through and piece together why Shire BEST would not receive funds. Another explanation is that the trust's charter as a private, nongovernmental institution makes it ineligible to directly receive levy-collected funds. If so, it is unclear why this factor was not discussed before compact close. One interviewee stated that MERA had identified "a lot of fudge in the budgets" proposed by ESCOM and EGENCO, and that it was unclear whether the tariff ever included money for Shire BEST and if so, whether MERA cut it. Because both ESCOM and EGENCO underwent management changes coinciding with these events, another hypothesis supposed that new leaders simply dismissed the promises of erstwhile leaders as the former leaders' preferences, relieving their organizations of the obligation to follow through on the question of funding Shire BEST.

In lieu of receiving funding through the MERA levy, EGENCO signed two MOUs with Shire BEST that have provided substantially lower levels of financial support than even under the low scenario. The first MOU of 200 million MWK ($275,000) was intended to cover the 2019/2020 fiscal year (FY). The actual amount received was 135 million MWK ($186,000), and Shire BEST was later informed these would be the total funds available for the 2019 to 2021 period, not just FY 2019/2020 (Shire BEST 2021a). In contrast, MCC had a target disbursement to the trust of $695,000 in 2019, meaning that the trust's actual funding was 27 percent of the target.[24] A second MOU was signed in April 2021 to cover Shire BEST from July 2021 to March 2022 with a grant amount of 220 million MWK ($273,000).[25] The trust's 2020/2021 financial statements state that "to comply with the MOU, cost-saving is being strictly observed, including reducing some staff time to 75 percent full-time equivalency" (Shire BEST 2021b). This applied to the CEO's staff time to maintain a 70:30 ratio between operations and administration. At the time of our data collection, no MOU had been signed to extend support for Shire BEST beyond March 2022.

Between fiscal years 2019/2020 and 2020/2021, funds available to Shire BEST decreased, as did the share of total expenditures spent on project costs, from 38 to 17 percent. Shire BEST had 159 million MWK available in FY 2019/2020 (Figure V.9) through money available from EGENCO's first

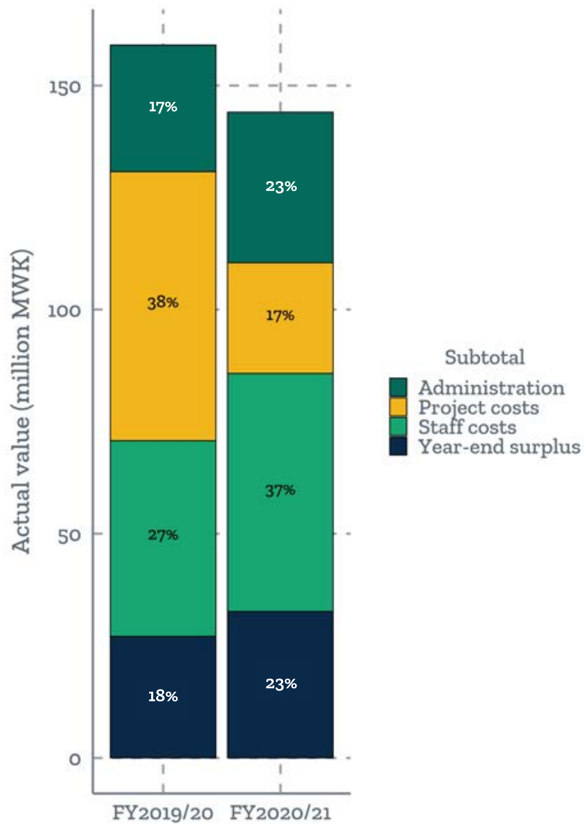
[23] ESCOM's base tariff application to MERA for 2018/2019 to 2021/2022 forecast that 12 billion MWK would be collected under the MERA 1 percent levy but does not document how levy funds would be used. The application is available at http://www.escom.mw/downloads/Electricity%20Base%20Tariff%20Main%20Submission%20to%20MERA%20by%20ESCOM%20Ltd.pdf.

[24] Per MCC's post-Compact indicator tracking table, the targeted values of PES funds disbursed to Shire BEST were $695,000, $648,000, and $709,000 for 2019, 2020, and 2021.

[25] Our understanding as of the end of the evaluation period is that the $273,000 would have been fully disbursed to Shire BEST. However, Shire BEST informed us in May 2022 that actual funds disbursed under the second MOU were 55 million MWK ($68,250). Confirmation of this number would only be available in 2022/Q3 when Shire BEST's financial statements for 2021/22 would presumably become available.

MOU, an in-kind donation of bamboo seedlings, and the value of assets donated by MMD. Total income the following year, inclusive of the 27 million MWK surplus carried over from FY 2019/2020, dropped to 144 million MWK. Project costs in FY 2019/2020 totaled 60 million MWK, and funded one implementing partner (described below), branding, meetings and seminars, fuel and per diems, and planting of 10,000 bamboo seedlings. These seedlings were received through a collaboration with the Ag Diversification Activity under the United States Agency for International Development's Feed the Future program. Project costs in FY 2020/2021 were primarily spent on bamboo planting, along with program-related travel costs and the commissioning of landscape designs to identify priority micro-catchment areas.

Figure V.1. Summary of Shire BEST's expenditures for FY 2019/2020 and FY 2020/2021



Source: Mathematica calculations using data from Shire BEST (2021a, 2021b).

Note: The audit reports use exchange rates of 728.25 and 805.90 to $1 US for 2020 and 2021, respectively. Year-end surpluses are carried over into the following financial year.

Since its inception, the trust has disbursed funding to one grantee, Training Support for Partners (TSP), which received about 35.6 million MWK ($48,900) in 2019/2020 to support catchment restoration activities in the Lisungwi-Mwetang'ombe sub-catchment in Neno District (Shire BEST 2021a).[26] The actual expenditure on this grant accounted for 59 percent of total project costs for the year. Although the TSP grant was budgeted for 90.8 million MWK, Shire BEST was forced to terminate the

[26] Based on an exchange rate of 736.36 MWK to $1 US, as per https://www.xe.com/currencytables/?from=USD&date=2020-01-01#table-section.

contract six months into the partnership in order to repurpose funds to cover Shire BEST's own operating costs. The trust approved the grant despite its own financial shortcomings, assuming Shire BEST's finances would improve with new revenue sources, but those sources never materialized. TSP's work under this grant included constructing contour marker ridges, swales, and silt traps; planting vetiver grass and bamboo; and registering designated plots for farmer managed natural regeneration. Before receiving support from the trust, the grant facility had also provided funding to TSP (see Velyvis et al. [2022]). TSP was selected as a grantee after the trust circulated a call for proposals, reviewed the submissions with support from trustees, and negotiated an MOU defining implementation locations and performance indicators.

At the end of our data collection period the trust was negotiating an MOU with another organization to distribute improved cookstoves that was ultimately not completed. Shire BEST had published a call for proposals offering grantees 4 million MWK for 12 months of implementation, scored those that were received, and had been making progress with a second implementing partner. Shire BEST and this implementer held multiple meetings to address which activities would be supported to define the geographic scope where work would be implemented. The MOU was ultimately aborted before contracting. The implementer claimed that 4 million MWK would only cover their costs for four months, whereas Shire BEST expected that grantees would carry out programming for the full 12 months.

RQ 2b. What is the trust's fundraising strategy to achieve sustainable financing over the long term? How was it developed?

Trust staff are actively engaged in fundraising efforts on multiple fronts. The most important efforts have been maintaining a continuous dialogue with EGENCO, both in requesting MOU renewals and determining whether there is any scope for receiving PES funds through the levy. The trust continues to have conversations with ESCOM, Illovo, Southern Region Water Board, and other stakeholders to request funding or program implementation opportunities and receives feedback and guidance from the trustees on these activities. The trust is not counting on any of these partnerships to yield the necessary funds, and so has also submitted, or plans to submit, funding proposals to various destinations. In 2021, it unsuccessfully submitted a concept note to the Global Fund for Ecosystem-based Adaptation (Global EbA Fund) to cover an approximately $250,000 award with Catholic Relief Services (CRS) as the lead partner. It planned to submit a proposal to the Green Climate Fund (GCF) through GCF's Simplified Approval Process Pilot Scheme (SAP), which if successful, would provide $10 million in funding over five years. IUCN would serve as both the technical partner and the accredited agency, a requirement for GCF support.[27] In 2021, Ilovo Sugar Malawi invited Shire BEST to submit a proposal to work on an existing flood management project in Chikwawa district, the outcome of which had not yet been determined during our data collection

> **"[EGENCO] appreciates the quandary of Shire BEST and they do appreciate that this is an organization that's trying to do something. I think if EGENCO was not feeling they were the sole benefactor of Shire BEST right now, they would feel a lot more comfortable that sustainability was not such an issue. Because I'm sure EGENCO has …. got all sorts of pressures with regards what kind of output Shire BEST is really giving given its circumstances." (BM3)**

[27] Shire BEST informed us in May 2022 that the Environmental Affairs Department has written a Letter of No Objection to the IUCN in regards to IUCN's collaboration with Shire BEST on the GCF proposal. The lead government department for the GCF proposal would be the Department of Water who has endorsed a draft proposal.

period.[28] Aside from writing specific proposals, secretariat staff have engaged organizations such as CRS, IUCN, and the United Nations Development Programme in identifying funding streams and partnership opportunities. Shire BEST also organized a Run for Shire virtual marathon in 2020 to raise funds from registration fees and partners who would be categorized as a "bronze" or "platinum" sponsor based on their support, with "platinum" partners giving a minimum of 5 million MWK ($6,900).[29] Shire BEST's financial statements for 2020/2021 indicate the marathon was budgeted with the goal of netting the organization 10 million MWK ($13,800), but actually brought in less than $400. As a result, Shire BEST has not had a systematic fundraising strategy or approach; rather, it has operated with a survival mindset since the first EGENCO MOU. It has pursued a variety of avenues and has engaged continuously with any stakeholders that have ever hinted at supporting or collaborating with the trust.

Prospective funders have limited insight into whether Shire BEST is an effective vehicle for allocating their resources. Although the trust has procedural standards in place through a set of documents covering the organization's governance, Shire BEST has supported only one grant in its practice. Therefore, it does not have a deep bench of organizational experience and best practices to communicate to funders. One interviewee stated, "the problem is receiving resources and then having nothing to showcase … this means funds will quickly dry up" (BM4). Many dimensions of trust effectiveness are simply unknown, such as the level of real-time assistance provided to grantees, the quality of oversight of implementers' activities, and the rigor of Shire BEST's M&E capabilities. Shire BEST would have accumulated more grantmaking experience had it taken over the small grant pilot program in its second and third years. MMCT, one of the consortium partners involved in the initial establishment of the trust (see Section I.D for more details), was reluctant to take on that role and lacked the capacity to administer the program. In year three of the grants program, allegations of fraudulent activity by the consortium precluded the trust from running the grants portfolio. As a result, Shire BEST missed out on the opportunity to gain first-hand experience in grantmaking which would have set it up for greater success at the end of the compact.

B. Factors affecting the trust's establishment

RQ 1. What implementation factors supported or hindered the establishment of the trust?

At the time of our interim evaluation data collection (Q4 2018), Shire BEST had not yet been fully established as a trust. Using the trust feasibility study from Spergel (2015) as a guide, Shire BEST would first need to complete several key steps, such as hiring an executive director, drafting employee terms of references, and securing funding before qualifying as established. Coen et al. (2019) documented the status of those steps during the interim evaluation, which we have since updated (Appendix Table C.1). All steps have either since been achieved or are no longer pertinent because they applied to trusts structured as endowments (for example, hiring an international investment manager).

The current CEO was crucial to enabling the trust to achieve the outcomes it has since the compact's close in September 2018. At that time, she was a trustee who volunteered her unpaid time in a secretariat-like capacity, "so that the trust would not die" when it had neither permanent staff nor funding. Funds from that first EGENCO MOU did not become available until nearly a year after the compact ended. After the signing of that MOU, she resigned her trustee position and became the CEO in July

[28] As of May 2022, after the evaluation data collection period ended, Shire BEST informed us Illovo has confirmed financial support of Shire BEST at the level of 66 million MWK for this project, 25 percent of which would fund the trust's administrative costs.

[29] An example flyer for the marathon is available at https://www.facebook.com/pages/category/Nonprofit-organization/Shire-Best-100707311507971/.

2019. She has been involved in all aspects of Shire BEST's functioning and has been the primary face of Shire BEST in making the case for supporting and sustaining the trust.

The trustees were also a major supporting factor in the trust's growth and completion of those initial implementation steps. Even when Shire BEST lacked funding and staff, the trustees met regularly and actively explored funding opportunities, which for obvious reasons was seen as paramount in achieving the other steps in Spergel (2015). Trustees could have left the organization but did not. To date, they have continued providing the secretariat feedback and guidance. One interviewee stated that trustees often accompany secretariat staff on meetings with government stakeholders, so that "it's not only one person speaking at these events" (BM1). This practice has been particularly helpful for the secretariat.

Stakeholders understood that sustainable land management is essential for the Shire River Basin, and the trust offered a means to achieve that goal. Stakeholders recognized that mechanical efforts to manage weeds and sediment (Chapter IV) attack only the symptoms and not the problem of unsustainable land management. More specifically, effective grantmaking by the trust could reduce the WSM costs borne by EGENCO and contribute to a more reliable electricity supply, in line with the project's intended long-term outcomes. As a result, there has been widespread recognition of the trust's role in addressing the "upstream" issues of soil and land management as a complement to the WSM activities. That recognition has opened doors to national and regional government stakeholders that Shire BEST has access to.

The funding available to Shire BEST provided a critical lifeline but was insufficient to support the trust's progress relative to what it could have achieved under targeted levels envisioned by MCC and MCA-Malawi. The funding was enough "to keep the lights on," but not enough to sustain programs, as evidenced by the early termination of the TSP MOU. Limited funding required that staff and the board dedicate an inordinate amount of time to fundraising and pursuing near-term revenue streams, because each EGENCO MOU covered a single year with no guarantee of renewal. Shire BEST's financial circumstances were a far departure from the low scenario of $700,000 in annual funding, which would have enabled only "some field results." For perspective, one interviewee shared that MCC estimated that $250,000 was the annual minimum required just to pay office rent and a small number of staff. The actual funding status meant staff and trustees had to divert time from other tasks, like developing a longer-term vision for how Shire BEST's investments could improve land use management and building relationships with prospective implementers.

Another barrier to the trust's establishment was a lack of other stakeholders to support the nascent trust. After MCC and MCA-Malawi's exit, no new organization has stepped in to support the trust. Although there had been talk of the World Bank playing a supporting role, given the significant overlap between the trust's objectives and the goals of the bank's $122 million Shire River Basin Management Program (Phase-1) Project, it appears that role has only taken shape in the form of the NWRA, a body the bank helped architect, becoming a trustee.[30]

C. Fidelity to logic model

Overall, we believe that the logic model for the environmental trust as sketched out in Figure I.1 is an accurate depiction *in principle* for how the trust is engaged within the ENRM Project as a vehicle for poverty reduction and economic growth. We do not believe that the model excluded important flows or interdependencies. *In practice*, the trust has been stalled at the inputs and outputs portion of the model

[30] Additional information on this World Bank project is available at https://projects.worldbank.org/en/projects-operations/project-detail/P117617.

and unable to achieve meaningful outcomes, such as reducing siltation and weed infestation, or reducing gender inequalities in the access to and control over productive resources. It is also unclear whether evidence on intervention effectiveness that has accumulated from the grant facility program will affect Shire BEST's grantmaking strategy, aside from providing general guidance about the types of interventions that are appropriate. As we discuss above, the biggest shortcoming has been the absence of sustainable funding at the scale needed to be an effective grantmaking body. As a result, an additional background factor that should have been included is the financial health and appetite of prospective trust donors, several of which at various points claimed financial duress that impaired their willingness to support Shire BEST. Relatedly, the logic model assumes that a functional trust could alter siltation and weed conditions in the Shire River Basin. That assumption is predicated on the trust having a substantially larger reach over agricultural practices in the basin than would be achievable for a trust of the size that had been envisioned during compact design.

VI. FINDINGS FOR THE OVERALL ENRM PROJECT

Summary of key findings

Impacts

- Both the total duration and frequency of turbine faults across the three HPPs have trended downward from the start of WSM equipment operations in 2018, signaling improved reliability of electricity.
- The three HPPs generated the most electricity per quarter at the end of the evaluation period but exceeded earlier production by small percentages and fell short of the compact target of 677 GWh/quarter.

Sustainability

- Interviewed stakeholders perceive that outcomes can be sustained if EGENCO continues to perform its WSM activities, as EGENCO's work is driving the improvements in efficiency of hydropower generation.
- Beyond EGENCO's committing the necessary funds to sustain its weeding and sediment removal activities, the key measure that can be taken to increase sustainability is to ensure that spare parts for the weed-harvesting and dredging equipment are well stocked and available.

As discussed in Chapter I, the ENRM Project's program logic situates the WSM, ENRM, and SGEF Activities as vehicles for achieving the compact goal of poverty reduction through equitable economic growth. Whereas Chapters IV and V evaluated the ENRM Project Activities separately, this chapter focuses on the aggregate impact of the WSM investments and the environmental trust, along with the synergies between the two. In this chapter, we answer the research questions detailed in Table VI.1, which address Project-wide achievements, unintended consequences, and key areas relevant to sustaining the Project's contributions. Our findings are based on the KIIs conducted with stakeholders from EGENCO, Shire BEST, MMD, and MCC as part of our activity-specific evaluations, along with administrative data provided by EGENCO and MCC's indicator-tracking table.

Table VI.1. Research questions addressed in the WSM Activity evaluation

Research question
1. Did the ENRM Project achieve its targeted intermediate and final outcomes and contribute to higher-level compact objectives listed below? Why or why not?
a. Outcomes: Reduced siltation and weed infestation in the Shire River Basin; increased efficiency of hydropower generation; improved electricity reliability and increased power generation
b. Compact objective: reduced poverty through economic growth
c. Were there any unintended consequences of the program (positive or negative)?
2. Based on the results of each activity's evaluation, what are stakeholders' perceptions of sustainability of outcomes achieved under the ENRM Project, and why?
a. What could or should be done to increase sustainability?

A. Final results from ENRM Project-wide activities

The ENRM Project intended to achieve synergies between the WSM, ENRM, and SGEF Activities that would jointly lead to improvements in electricity supply with the goal of reducing poverty and fostering equitable economic growth. In this section, we review the evidence available on the effects of Project Activities on hydropower production outcomes and discuss the linkages between the ENRM Project and the compact goal. We then describe for the Project the most significant unintended consequences that surfaced in our evaluation's data collection. In the last subsection, we revisit the program logic model considering the overall ENRM Project, not individual Activities as in previous chapters, and share our perspective on meaningful differences between the logic model and the Project's actual execution.

1. Impacts on intermediate and final outcomes

In Chapter IV, we shared our findings on how the new WSM assets at Liwonde and Kapichira separately affected hydroelectricity measures that were directly linked to weed- or sediment-caused losses of electricity. The evidence there supports the claim that the WSM Activity improved hydropower operations across the three stations and led to fewer generation losses than were predicted under the counterfactual of no ENRM Project. In this section, we set aside the distinction between "weed-caused" and "sediment-caused" losses and examine aggregate indicators representing the Project's intermediate and final outcomes: reduced siltation and weed infestation, increased efficiency of hydropower generation, improved reliability of electricity, and total production of electricity. Where the data permit, we present results at the level of individual HPP and as a total across the three Shire River HPPs.

RQ 1.a. Did the ENRM Project achieve its targeted intermediate and final outcomes (that is, reduced siltation and weed infestation in the Shire River Basin, increased efficiency of hydropower generation, improved reliability of electricity, and increased power generation)? Why or why not?

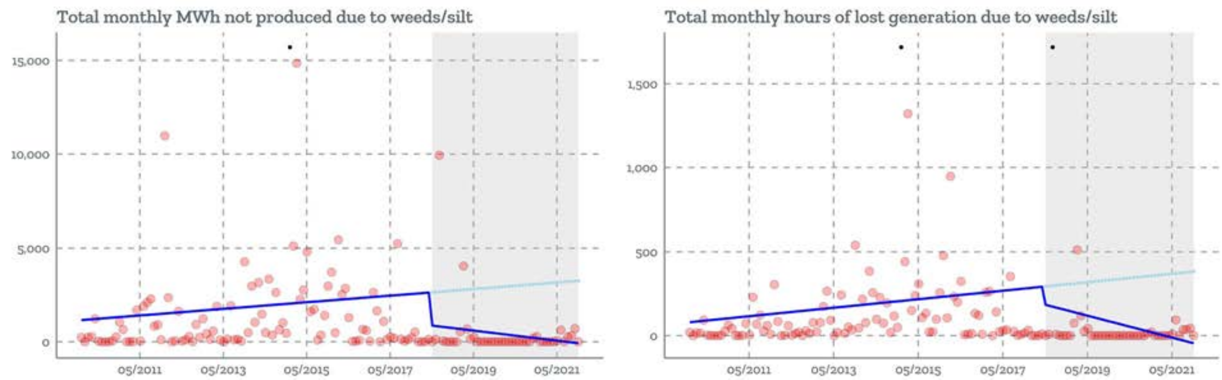
Effects of reduced siltation and weed infestation

The ENRM Project resulted in substantial reductions in electricity losses resulting from weeds and silt, in terms of output (MWh) as well as total hours of production. In Chapter IV we reported ITS results that quantified the impact of the WSM Activity on electricity losses separately based on the cause of the loss, as reported by EGENCO. Here we generalize that approach by combining losses and not differentiating between causes. We count May 2018 as the start of treatment because that is when the new weed harvesters began operating. ITS models for both total electricity losses and total hours of lost generation capacity demonstrate clear reductions in the post-treatment period (Figure VI.1). These stepwise declines are respectively 1.74 GWh of avoided monthly electricity losses and 79 hours of less downtime across all three hydropower plants (Table VI.2, row 1) and represent the average difference in levels between the pre-treatment and post-treatment period.[31] The post-treatment trends are negative for both models (row 3), indicating that losses continued to decrease month on month after the WSM activities began, and are heavily influenced by a small number of extreme values occurring immediately following the start of treatment. Absent those outliers, post-treatment trends would have been flat, indicative of the Project's acting more like an on-off switch that turned on when the equipment became available, than a situation in which benefits gradually accumulated over the post-treatment period.[32] *The average post-treatment reduction in monthly losses was 2.6 GWh of electricity and 269 hours of lost generation, once both the stepwise change and differential trends are considered* (Table VI.2, row 7). Although the mean value of lost electricity supply in the post-treatment period is 424 MWh/month (Table VI.2, row 9), two outliers from 2018-19 inflate that value. In comparison, the mean losses for the last 12 months of data were 164 MWh/month or 1,968 MWh per annum. As a result, the end-of-compact target of keeping losses of electricity due to weeds and sediments under 2,320 MWh was achieved only if outlier values were removed from the post-treatment period.

[31] The stations covered in our analysis account for 366.7 MW of nameplate capacity. At an availability rate of 100 percent, they would collectively produce 273 GWh of electricity in a 31-day month. The avoided losses therefore represent a minimum of 0.6 percent of electricity generation capacity, because plant availability represents only internal losses, not losses due to depressed electricity demand or weather-induced reductions in reservoir water levels.

[32] We note that post-treatment trends indicate a transition point occurring sometime between 2021 and 2022 of plants generating *negative* losses. This is an artifact of imposing linearity on the trends, which improves interpretability of model results but does not constrain predictions to being non-negative.

Figure VI.1. ITS results for monthly hydroelectricity losses due to weeds or silt combined across Nkula, Tedzani, and Kapichira



Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: The gray rectangle represents the treatment period, which we identify as beginning when the Liwonde weed-harvesting equipment was operational in May 2018. The light-blue dotted line projects the pre-treatment trend into the post-treatment period and represents the “no project” counterfactual. Observed values that are 2.5 standard deviations or more away from the sample mean are top-coded at that value for display purposes (in black), but their actual values are used in all regression models. The regression coefficients from the primary specification ITS model are displayed in Table VI.2. N = 144 monthly observations for January 2010 through December 2021.

A striking finding from both panels in Figure VI.1 is the reduction of month-to-month variability in performance in the post-treatment period. Consider the upper subfigure, in which a sizable share of months in the pre-treatment period suffer lost generation in the range of 1,000 to 6,000 MWh. From June 2018 onwards, only two months experienced losses of that magnitude or higher. The probability that a month would undergo no electricity generation losses increased considerably in the post-treatment period. The lower subfigure shows a comparable pattern in the difference between pre-treatment and post-treatment periods. As discussed in Chapter 4, one EGENCO stakeholder shared that changes in Shire River water flow contributed to reducing the amount of silt-related electricity losses, independent of the WSM Activity. We also note that extreme outlier values do not disappear with the advent of the WSM investments; there have been months following the operation of the weed-harvesting equipment that experienced large production losses.

Table VI.2. ITS regression model results for total electricity losses combined across Nkula, Tedzani, and Kapichira due to weeds and silt

		Outcome (monthly)	
Row #	**Variable**	**MWh not produced (1)**	**Hours of lost generation (2)**
1	Post	-1741.742	-102.090
		(1683.421)	(233.590)
2	Time	14.688	2.115 *
		(11.156)	(1.165)
3	Post x Time	-37.122	-7.580
		(37.924)	(6.311)
4	Precip	20.249	1.826
		(16.824)	(1.855)
5	Precip (Lag 1)	-2.512	-0.096
		(4.224)	(0.451)
6	Constant	-415.019	-41.585
		(1046.644)	(86.288)
7	Average estimated treatment effect	-2,558	-269
8	Pre-treatment mean	1905.362	185.352
9	Post-treatment mean	424.053 **	70.401
		(*p* = 0.039)	(*p* = 0.182)
10	N	144	144
11	R^2	0.095	0.074

Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: Robust standard errors are reported in parentheses. The *p*-values reported in row 9 are from two sample t-test comparison of means between pre-treatment and post-treatment values. Each model includes contemporaneous and lagged monthly rainfall totals as measured at Liwonde using data from CHIRPS. We count June 2018 as the start of the "Post" period, as the first full month following the May 2018 delivery of weed-harvesting equipment. Outcome values are summed across all machines operating at an HPP. The average estimated treatment effect is the mean difference between the counterfactual and the fitted values over the post-treatment period. N = 144 monthly observations for January 2010 through December 2021.

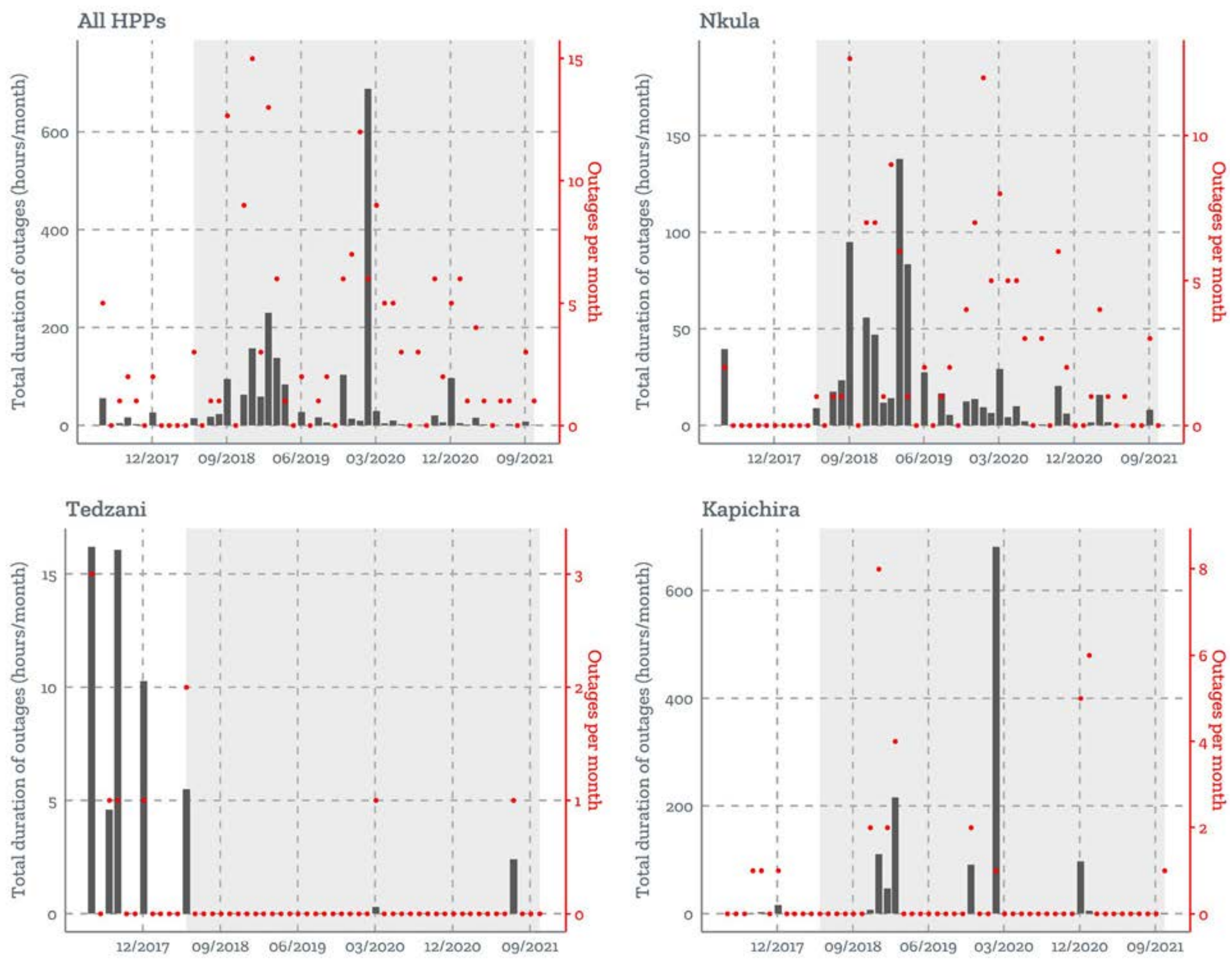
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

If the effects had been driven exclusively by MCC's investments, improvements in HPP performance due to problems caused by weed and silt would have occurred only *after* WSM Activity operations began. In both subfigures in Figure VI.1, values clustering near the horizontal axis (that is, at or close to 0 MWh and 0 hours, respectively), suggest that the turning point in HPP performance may have happened *prior* to the start of the use of the weeding equipment. Our best understanding is that equipment provided through the World Bank's Shire River Basin Management Program (Phase 1), such as the improved weed control system installed at Kamuzu Barrage (IEG Review Team 2020), is the most likely explanation for any observed improvements in HPP performance that are specifically related to weeds and sediment aside from MCC's investments.

Improved electricity reliability

Both the total duration and the frequency of turbine faults across the three HPPs have trended downward from the start of WSM equipment operations in 2018, signaling improved electricity reliability. These improvements have been driven largely by Nkula (Figure VI.2, top right – each panel is displayed with its own vertical axis range), which experienced a visible reduction in turbine outage time (left y-axis, denoted in bars) and the number of faults (right y-axis, denoted in red points). Outages at Nkula continue to occur on an intermittent basis but are resolved faster than in 2018 and 2019, when several months registered more than 50 hours of downtime across Nkula's two stations (Nkula A and Nkula B). We note that periods during which HPP equipment was under repair or maintenance are not considered fault episodes. For example, Tedzani Unit 1 was under rehabilitation from November 2017 through November 2018 but is not listed as an outage episode in Figure VI.2.

Figure VI.2. Frequency and total duration of turbine outages over time by month



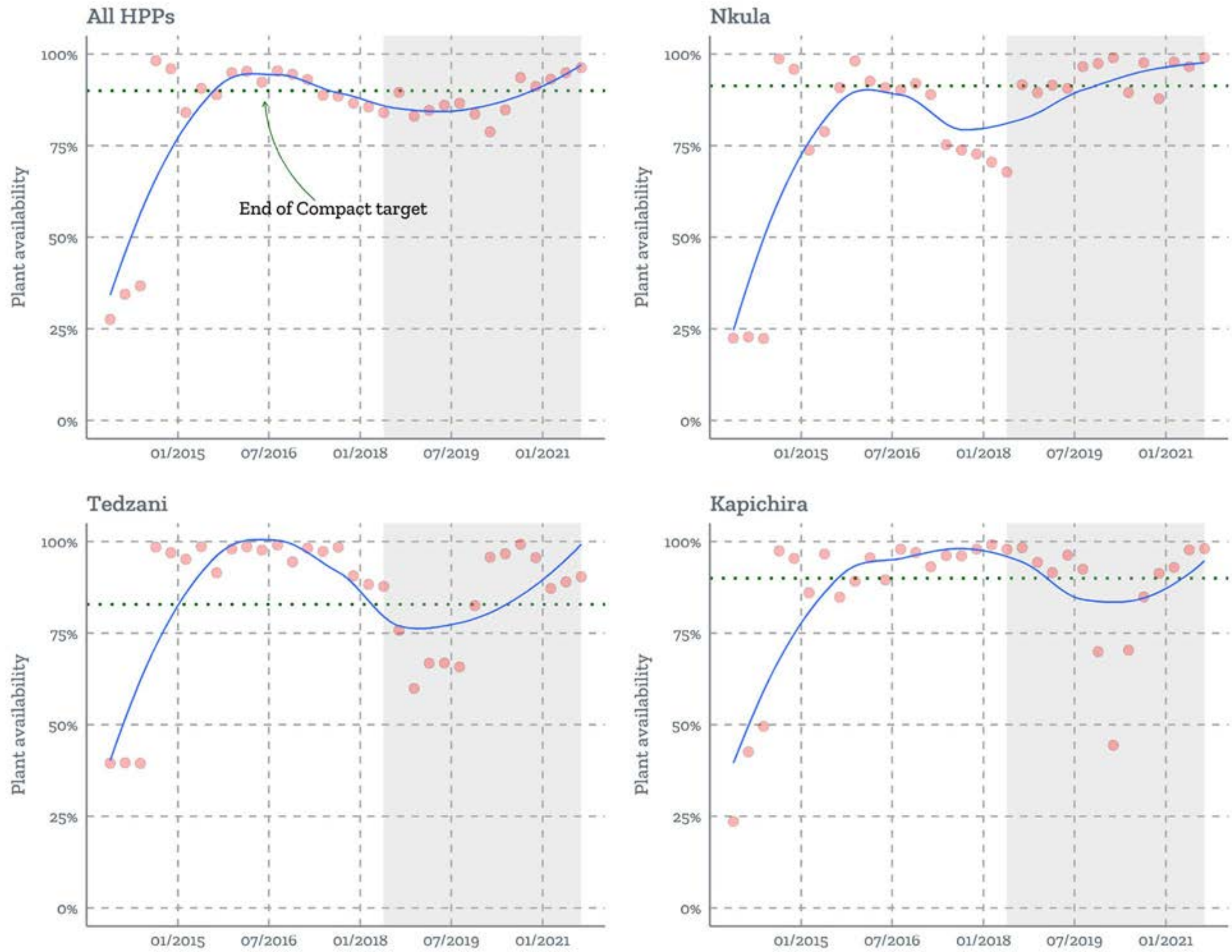
Source: Mathematica calculations using data from EGENCO.

Note: The gray rectangle denotes the post-treatment period, which starts in June 2018 as the first full month operating any MCC-funded WSM equipment. Plant-level values are sums of monthly, station-level data. The top-left panel is the sum of all monthly turbine outages across Nkula, Tedzani, and Kapichira. N = 53 monthly observations for July 2017 through November 2021.

Plant availability, which measures the percentage of HPP capacity that can generate electricity and is penalized when plants undergo extended repair or maintenance periods, was at the same level in 2020–2021 as observed before any of the ENRM Project components were in effect. Across the three HPPs individually as well as in aggregate, plant availability levels at the end of the evaluation period often exceeded 90 and 95 percent, but those magnitudes had been recorded in 2015 and 2016 (Figure VI.3). While Nkula registered a trough in availability in 2017 and 2018, ranging between 65 percent and 75 percent, this dip was due to rehabilitation works occurring on the Nkula A plant (Appendix D, Figure D.1). The troughs in availability at Tedzani preceding the treatment period suggests that availability levels there may have decreased further in time had the ENRM Project not taken place. Kapichira, on the other hand, experienced a trajectory distinct from the others; its overall availability was stable between 2016 and 2019, and only after the WSM Activity was well under way underwent a sharp reduction, with several quarters posting availability values below 75 percent.[33] By the end of the evaluation period, all plants had surpassed their end-of-compact targets (shown respectively as the horizontal dotted green lines in each panel), though each plant spent several months below the target availability levels during the treatment period.

[33] In Appendix D, Figure D.1, we disaggregate power plant availability levels to the station level to demonstrate that a plant's inter-station dynamics vary across HPPs. When not at 100 percent, Tedzani's stations appear to alternate in availability, whereas Kapichira I and Kapichira II tend to concurrently register lower availability values. Even when an HPP records low availability at the plant level, one station may still be at or near full capacity.

Figure VI.3. Power plant availability over time by quarter



Source: Mathematica calculations using data from EGENCO.

Note: The gray rectangle denotes the post-treatment period, which starts in June 2018 as the first full month operating any MCC-funded WSM equipment. The blue line is a loess smoother through each plant-specific time series. The dotted green horizontal lines denote the end of compact target value for that plant, which we calculate using station-specific capacities as weights. Plant-level quarterly values are the weighted average of monthly, station-level sums using station capacity as weights. The top-left panel is the weighted-average availability for Nkula, Tedzani, and Kapichira. N = 32 quarterly observations for 2013/Q4 through 2021/Q3.

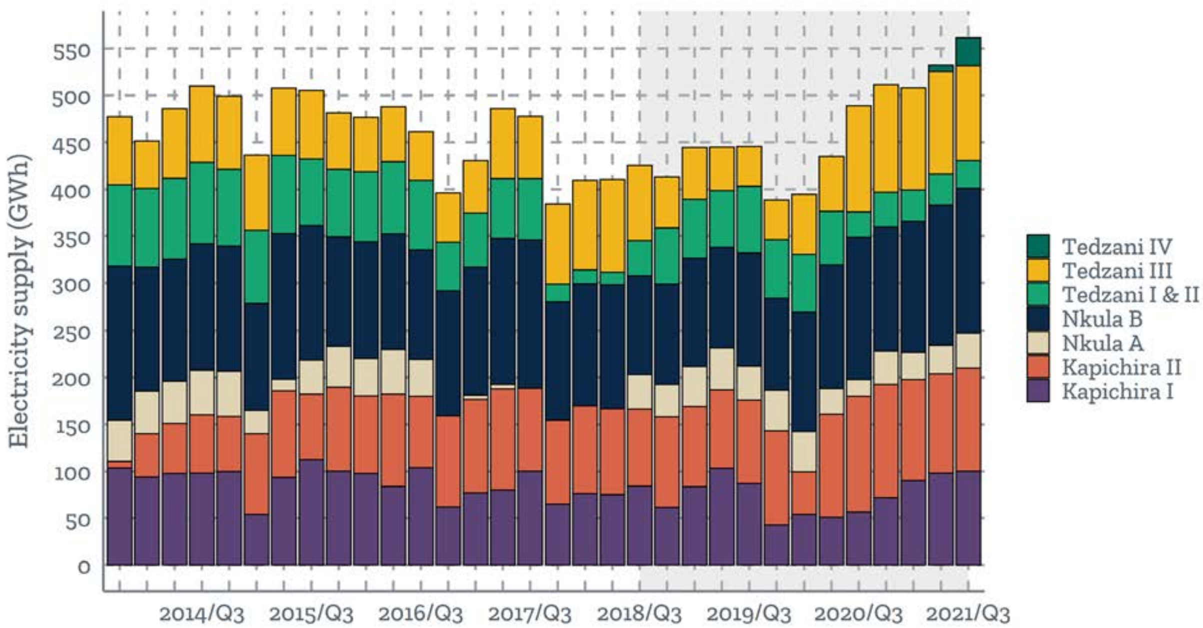
Increased power generation

The three HPPs generated the most electricity per quarter at the end of the evaluation period but exceeded earlier production by small percentages and fell short of the compact target of 677 GWh/quarter. In the last four quarters, spanning 2020/Q4 through 2021/Q3, average electricity production was 519 GWh (Figure VI.4).[34] That represents only a 7 percent increase over the 485 GWh average quarterly supply over 2014–2015. However, if compared against calendar year 2017, which experienced a demonstrable reduction in electricity output relative to earlier periods, the 2020–2021 average represents a 17 percent increase in supply. Some of the observed variability in station-level

[34] To make meaningful comparisons against earlier periods before Tedzani IV was completed, this value excludes electricity produced at Tedzani IV.

supply was driven by planned outages and rehabilitation projects. For example, Tedzani III, shown in brown, was upgraded from 26.35 MW to 31 MW, hence the larger output values over the 2020 and 2021 period relative to earlier years. If the highest quarterly output (532 GWh in 2021/Q3) was sustained for four quarters, the total would be 2.1 TWh, which still falls short of the compact annual target of 2.6 TWh.[35] Relative to the 2012–2013 baseline annual production of 1.81 TWh, the 2020/Q4–2021/Q3 period marks a 14 percent increase. *If we assume that the difference between the baseline (454 GWh/quarter) and the 2020/21 period (519 GWh) represents the supply improvement due to compact investments, then the monthly average 2.6 GWh reduction in electricity losses from weeds and sediment (as estimated above) accounts for 12 percent of the total electricity supply gains.*

Figure VI.4. Quarterly electricity supply by HPP station (GWh)



Source: Mathematica calculations using data from EGENCO and MCC.

Note: The gray rectangle denotes the post-treatment period, which starts in 2018/Q3 as the first full quarter operating any MCC-funded WSM equipment. Monthly data from July 2017 to September 2021 were summed by quarter to match the cadence available in MCC's closeout ITT. N = 32 quarterly observations for 2013/Q4 through 2021/Q3.

2. Impacts on compact goals

RQ 1.b. Did the ENRM Project contribute to higher-level compact objectives (that is, reduced poverty through economic growth)? Why or why not?

We are unable to provide rigorous evidence on whether the ENRM Project contributed to poverty reduction or equitable economic growth. The results reported above demonstrate that the Project contributed to increases in electricity supply and reliability from the three Shire River HPPs, but those gains cannot be credibly interpreted as precursors to job growth or improvements in household welfare (for example, reducing exposure to indoor air pollution by switching to electric cooking) in the absence of a credible research design to answer this specific question. Although access to electricity is an essential

[35] We exclude from all calculations electricity generated at Wovwe Power Station, which is not located on the Shire River.

input into economic activity, and unstable supply can have adverse effects on both households and businesses, evidence is not available in this evaluation for asserting that the ENRM investments sufficiently altered electricity performance to have affected household or business decisions at a scale that could be meaningfully quantified. Although our cross-case analysis (Velyvis et al. 2022) finds that households who participated in grant facility-supported programs reported higher incomes and crop yields, systematic data on all their revenue streams and costs was not collected, nor was information on nonparticipants collected to form a counterfactual of participant outcomes in the absence of the ENRM Project.

3. Unintended consequences of project activities

RQ 1.c. Were there any unintended consequences of the program (positive or negative)?

Interviewed stakeholders, secondary data, and related documents do not indicate there were any material unintended consequences, either positive or negative.

4. Fidelity to logic model

In Chapters IV and V, we examined how the actual experience of the WSM Activity and the environmental trust as standalone components compared to how they were situated in the program logic. Here we address the logic model of the ENRM Project as a whole and focus on the connections and relationships *between* activities.

The key deviation between the ENRM Project in execution and the logic model is the degree to which the ENRM and SGEF Activities contributed to reductions in siltation and weed infestation in the Shire River Basin. Although programs supported by the grant facility, and those which could be funded through an invigorated Shire BEST, have engaged in activities aligned with SLM promotion and catchment restoration, we believe that such programs have simply not operated at a scale necessary to affect Basin-wide outcomes demonstrably. As a result, any reductions in siltation and weed growth affecting hydropower operations are likely to be due exclusively to EGENCO's operations under the WSM Activity.

B. Prospects for project sustainability

RQ 2. Based on the results of each activity's evaluation, what are stakeholders' perceptions of the sustainability of outcomes achieved under the ENRM Project, and why?

Interviewed stakeholders shared that outcomes can be sustained if EGENCO continues performing its WSM activities, because it is EGENCO's work that is driving the improvements in hydropower generation efficiency. Interviewees do note that the most sustainable arrangement would be one in which the need to continue the WSM activities as they have been performed is preempted by the adoption of SLM practices throughout the Shire River Basin. That would require sustained behavioral change in how land is cultivated and forests managed, which Shire BEST is positioned to foster, and could, if funding to support programs at scale were made available to it. The continuity of EGENCO's WSM operations are likely to hinge on whether its leadership believes the gains in electricity supply offset the WSM costs, which will eventually grow as the equipment ages and requires more maintenance and spare parts.

Because Shire BEST has had little impact on the Basin's SLM practices, its contribution to Project outcomes has also been limited, which makes an assessment of its key sustainability factors challenging. As discussed in Chapter V, a necessary but not sufficient condition for Shire BEST to be able to achieve its goals of catchment restoration and expansion of SLM practice adoption is a significant increase in funding.

RQ 2a. What could or should be done to increase sustainability?

Beyond EGENCO's committing the necessary funds to sustain its weeding and sediment removal activities (which interviewees told us already happens through their standard budgeting procedures), the key measure that can be undertaken to increase sustainability is to ensure that spare parts for the weed-harvesting and dredger equipment are well stocked and available. Interviewees referred to cumbersome procurement processes and delays in receiving parts from foreign suppliers as potential and actual barriers to receiving those parts on time. Such delays can disrupt operations and negate gains accrued to date, because the problems posed by weeds and sediment are continuous flows that will accumulate under inaction.

Funding Shire BEST at the levels proposed in their strategic plan (Shire BEST 2018) would increase the sustainability of the ENRM Activity's impacts and reduce reliance on mechanical means to manage weeds and sediment. Our results show that the WSM Activity has effectively improved HPP performance across multiple dimensions, but those activities are not solving the underlying problem. In addition to being costly in both labor and equipment needs, WSM activities also create untoward environmental effects, through diesel fuel combustion and occupation of land for disposal that could be used for other purposes. Shire BEST presents the most promising channel for engaging farmers, community groups, and other landholders to carry out the sustainable land management practices that the grant facility promoted through the ENRM and SGEF grantees. If Shire BEST was to be funded at the appropriate level and was effective in carrying out its mandate, its activities should reduce the need for EGENCO to engage their WSM equipment at their current intensity.

We believe there are two related courses of action that EGENCO might undertake to increase sustainability. First, they could evaluate whether efficiencies in the procurement process can be introduced. Interviewees shared that the various approvals required to make parts purchases can add substantial delays to receiving the equipment. There may be scope for expediting some of those steps or requiring that turnaround times be completed within a mandated duration. Our understanding is that automating portions of the procurement process may be another way to guarantee that parts are always available to minimize downtime. For example, a computerized inventory management system could log the expected operational life of different equipment components and trigger automated purchase requests to ensure that some minimum inventory is always on hand, rather than rely on on-site staff to make routine manual inspections of equipment availability. Second, interviewees at Kapichira remarked that several of the engines used on the dredge and in the boat fleet are from manufacturers with no Malawi presence (for example, John Deere, Honda). EGENCO engineers could consult manufacturers with in-country suppliers (such as Yamaha) to determine whether engines should be substituted for the sake of having more predictability over spare parts availability, and potential access to local service teams who could provide advanced maintenance work if needs were to exceed the capabilities of EGENCO staff.

VII. CONCLUSION AND RECOMMENDATIONS

For this report, we conducted separate evaluations for the WSM Activity and the environmental trust. We examined the interactions and connections between the WSM Activity and the trust from the perspective of the overall ENRM Project. A companion report (Velyvis et al. 2022) that presents case study analyses on five ENRM and SGEF grantees complements these evaluations. In this final chapter, we summarize key findings (Section VII.A), describe key analytical limitations (Section VII.B), and present concluding thoughts and recommendations for further research (Section VII.C).

A. Summary of key findings

In Table VII.1, we consolidate our evaluation's main findings from Chapters IV, V, and VI, and list the guiding research questions.

Table VII.1. Summary of key findings from ENRM Project evaluation

Main research questions	Key findings
WSM activity evaluation	
1. How was the activity implemented?	• Interviewees stated that the World Bank's investments in weed management did not impact which equipment was procured or how EGENCO has used the equipment. • EGENCO received the Kapichira dredge within the compact period. But the dredge was not fully operational until April 2020, about 18 months after the compact closed. In 2019, it became evident that the dredge required technical modifications to be operated properly. • Although MCC and MCA-Malawi did not have an end-of-compact target for the volume of weeds to be removed at Liwonde Barrage, the annual tonnage removed has increased substantially since the equipment began operating in May 2018.
2. To what extent did the activity restore active storage at the hydropower plants during the compact and after it ended?	• Estimates of the change in active storage capacity at the HPPs are not available, because bathymetric surveys have not been conducted recently. • Dredging operations at Kapichira from April 2020 to date have exceeded the targets defined in Fichtner (2014). In 2021, 729,000 m^3 of sediment was dredged, whereas the sediment management strategy indicated that an annual maximum of 616,000 m^3/year would be required.
3. Did the new weed harvesters and dredgers affect power plant operations and power generation after the compact ended?	• The weed harvesting equipment contributed to an overall reduction in weed-caused electricity losses at each of the Shire Cascade HPPs. HPPs experienced fewer hours of weed-caused plant downtime after the arrival of the new harvesters. Among the three HPPs, the Nkula plant experienced the largest absolute reduction in average monthly megawatt-hours not generated because of weeds, dropping from 355 to 144 MWh in the post-compact period. • Across each of the three HPPs, the amount of electricity that was not produced because of sediment dropped to zero in the post-treatment period, as per data EGENCO shared with us. The total plant downtime that HPPs experienced, measured as the number of hours for which turbines were not operating because of silt, also dropped to an average of zero hours per month in the post-period.

Table VII.1. *(continued)*

Main research questions	Key findings
4. How do the power plants ensure appropriate maintenance and repair of the equipment provided under the WSM activity?	• EGENCO has developed equipment sustainability plans that call for stocking sufficient spare parts, training appropriate staff, and conducting regular service checks. • Procuring spare parts has been challenging, because local suppliers do not stock the relevant items, such as conveyor meshes, and the procurement process involves several steps, each of which can cause delays.
5. What are stakeholders' perceptions of the sustainability of outcomes of the WSM activity?	• EGENCO interviewees stated that there is a budget line item to support expenses related to weed management and a charge code against which expenditures are reported. • Without significant changes in upriver land management practices, EGENCO will have to continue performing weed and sediment management activities to sustain these benefits and will need to identify additional areas for sediment disposal.
Environmental trust evaluation	
1. What implementation factors supported or hindered establishment of the trust?	• The current CEO was crucial to enabling the trust to achieve the outcomes it has since the compact's close in September 2018. • Stakeholders understood that sustainable land management is essential for the Shire River Basin, and the trust offered a means to achieve that goal. • The funding available to Shire BEST provided a critical lifeline but was not sufficient to achieve the level of grant-making envisioned by MCC and MCA-Malawi.
2. To what extent is the trust on track to reach administrative, operational, and financial sustainability?	• Funding from the MERA-approved electricity levy never materialized, and stakeholders offer various explanations for why, including that the verbal agreement for EGENCO to provide Shire BEST with funding was not legally binding, and that the trust's status as a private institution makes it ineligible to receive levy funds. • The trust's secretariat comprises two permanent staff members who are supported by a board of nine trustees (all seats are filled). Many of the most important organizations in Malawi's energy and water sectors sit on the board. • Since 2019, EGENCO has signed two MOUs with Shire BEST that would have funded the trust with \$550,000, with the expectation that funds be used in a 70:30 ratio between operations and administration. • Since its inception, the trust has disbursed funding to one grantee, Training Support for Partners (TSP), which received about 35.6 million MWK (\$48,900) in 2019–2020 to support catchment restoration activities in the Lisungwi-Mwetang'ombe sub-catchment in Neno District. This contract was terminated after six months because Shire BEST lacked sufficient funding to continue support. • Trust staff are actively engaged in fundraising efforts on multiple fronts. The most important efforts have been maintaining a continuous dialogue with EGENCO, both in requesting renewals of memoranda of understanding and determining whether there is any scope for receiving PES funds through the levy.

Table VII.1. ***(continued)***

Main research questions	Key findings
Overall ENRM project evaluation	
3. Did the ENRM Project achieve its targeted intermediate and final outcomes and contribute to higher-level compact objectives? Why or why not?	• Our data indicates the ENRM Project resulted in substantial reductions in electricity losses due to weeds and silt, in terms of output (MWh) and total hours of production. The average post-treatment reduction in monthly generation losses across the three HPPs was 2.6 GWh of electricity and 269 hours of downtime. • Both the total duration and frequency of turbine faults across the three HPPs have trended downward from the start of WSM equipment operations in 2018, signaling improved electricity reliability. • The three HPPs generated the most electricity per quarter at the end of the evaluation period but exceeded earlier production by small percentages and fell short of the compact target of 677 GWh/quarter. • We cannot provide rigorous evidence on whether the ENRM Project contributed to poverty reduction or equitable economic growth.
4. Based on the results of each activity's evaluation, what are stakeholders' perceptions of sustainability of outcomes achieved under the ENRM project, and why?	• Interviewed stakeholders shared that outcomes can be sustained if EGENCO continues performing its WSM activities, because it is EGENCO's work that is driving improved efficiency in hydropower generation. • Beyond EGENCO committing the necessary funds to sustain its weeding and sediment removal activities (which interviewees told us already happens through its standard budgeting procedures), the key measure that can be undertaken to increase sustainability is to ensure that spare parts for the weed harvesting and dredger equipment are well-stocked and available.

B. Limitations of evaluation

A key limitation of this evaluation, and specifically the WSM Activity, is the degree to which results can be generalized to other contexts where land management practices directly affect electricity reliability and supply. Although the ITS regression approach is among the most rigorous research designs applicable for evaluating the weeding and dredging activities, our results might not generalize to comparable interventions conducted elsewhere. The results are based on a sample size of one location where new weeding equipment was provided, and one location where new dredging equipment was provided. We therefore were able to observe the operations under only one set of circumstances. Results might have been dramatically different if another engineering team was responsible, or if equipment from an alternative manufacturer was purchased. Similarly, our estimates for Activity impacts would likely have been very different if Malawi faced a prolonged drought or recurring floods over the study period. The ultimate effectiveness of the weeding and dredging interventions is the result of numerous factors other than the provision of the equipment, including, among others, the competence with which staff operate the machinery, the financial support given to maintenance activities, and the degree to which corporate leaders monitor the activity. This evaluation demonstrates that when the necessary implementation factors are present, positive impacts can arise, but we cannot generalize about project effectiveness if one or more of those factors are absent. As factors and circumstances that are essential for project success differ across contexts, so too should expectations about the impacts equipment will have on HPP performance and electricity supply.

C. Conclusion

Less than 20 percent of Malawians have access to electricity and the economic, social, and environmental benefits it offers over traditional fuels. Among those households and businesses with access to electricity, service can be intermittent and unreliable with adverse effects on household welfare and business productivity. Although building new assets to generate electricity is one way to improve electricity supply and reliability and potentially expand access, improving the operational performance of existing generation assets by removing obstacles to achieving their maximum potential is another. Moreover, Malawi's dependence on hydropower reveals that the health of an energy sector is not determined solely by its generation assets or transmission and distribution infrastructure but also the environmental conditions in which its HPPs are situated, given the dominance of hydropower in the country's energy mix. In Malawi, that manifests as electricity losses due to aquatic weed infestations and sediment deposits that force turbine shutdowns and equipment failures and further complicate the task of balancing electricity supply and demand.

The ENRM Project sought to improve HPP performance and overall electricity supply through two channels. The first channel was to provide new equipment to increase active storage capacity and resolve the weed infestation and sediment deposition problems that had been accumulating before the compact's investments. The second channel addressed the root causes of weed and sediment accumulation by funding programs to encourage SLM adoption throughout the Shire River Basin, with the intent of reducing erosion and nutrient runoff. Success through this second channel would help alleviate, but not eliminate, the need for the first channel. Although some erosion and runoff is inevitable, the Project intended for a new equilibrium to emerge in which preventative SLM measures would become the primary means of stemming weed and sediment growth. Relatedly, the WSM Activity equipment will continue to operate in a maintenance mode, similar to how operations at Kapichira will transition from a capital dredging strategy to a maintenance dredging strategy once it has achieved its active storage capacity target.

Our evaluation finds that electricity supply both increased and improved because of the WSM Activity by reducing generation losses caused by weed and sediment buildup. We did not find any evidence that the environmental trust's activities were key contributors to those loss reductions, because Shire BEST has not yet begun to fund soil and land management activities to the degree where basin-wide impacts would be observable. Although the WSM Activity and the environmental trust were designed to address limited electricity supply and underperforming HPPs—a relatively unique problem specific to Malawi—future investments with analogous aims could benefit from evaluations that examine the three following dimensions. First, more research could be done on the benefits and challenges of donor collaboration, especially in domains with substantial overlap, as was the case when both MCC and the World Bank invested in weed management improvements in Liwonde. Second, the duration of the nonnegotiable five-year compact naturally creates risks for activities that are delayed and addressed toward the end the compact, as was the case with the environmental trust. Further research should be done to identify the most important factors that force implementation spillovers beyond the five-year compact window to ensure that compact activities are rightsized. When those delays are not resolvable, research on options to transfer or transition management, funding, and oversight to other donors, to enable activities to sufficiently mature before donor exit, could yield new possibilities for maximizing project sustainability. Lastly, there are real trade-offs between establishing institutions from scratch and rehabilitating or upscaling existing institutions. Future compacts should consider capitalizing and energizing institutions to determine whether institutional reform can be a faster and more cost-effective way to achieve societal change than standing up new institutions that lose their primary benefactor at the end of the compact.

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Appendix A.

Research questions by evaluation report

Table A.1 presents a side-by-side comparison of the research questions examined in the interim reports (Coen et al. 2019; Velyvis et al. 2019) and those examined in the final report. Research questions under the ENRM and SGEF grant facility are addressed in the accompanying final evaluation report (Velyvis et al. 2022).

Table A.1. Research questions addressed in the interim and final evaluation reports

Research questions – Interim report	Research questions – Final report
Weed and Sediment Management evaluation	
1. How was the activity implemented? a. Was the activity implemented as planned? Why or why not? b. Which implementation factors supported or hindered the effectiveness of the activity? c. Did the equipment purchased perform as expected in terms of the quantities of sediment dredged and weeds harvested?	1. How was the activity implemented? a. How did actual equipment purchase deviate from the original plan? How did the plan change due to other donor-funded interventions at the Liwonde barrage? b. Did the equipment actually purchased perform as expected in terms of the quantities of sediment dredged and weeds harvested?
2. To what extent did the activity restore active storage at the hydropower plants during the compact and after it ended?	2. To what extent did the activity restore active storage at the hydropower plants during the compact and after it ended? a. How did implementation of the dredging operations and disposal compare to the sediment management strategy?
3. Did the new weed harvesters and dredgers affect power plant operations during the compact and after it ended? a. To what extent did the equipment change power generation? b. How did the use of the equipment and related improvements vary by hydropower plant?	3. Did the new weed harvesters and dredgers affect power plant operations and power generation after the compact ended? a. How did the use of actually purchased equipment and related improvements vary by hydropower plant?
4. How do the power plants ensure appropriate maintenance and repair of the equipment provided under the WSM activity?	4. How do the power plants ensure appropriate maintenance and repair of the equipment provided under the WSM activity?
5. What are stakeholders' perceptions of the sustainability of outcomes of the WSM activity?	5. What are stakeholders' perceptions of the sustainability of outcomes of the WSM activity?
Environmental Trust evaluation	
1. What implementation factors supported or hindered the establishment of the trust?	1. What implementation factors supported or hindered the establishment of the trust?
2. To what extent is the trust on track to reach administrative and operational sustainability? a. Did the trust establish a funding mechanism, such as Payment for Ecosystems Services, and obtain sufficient capital to sustain grant investments beyond the life of the compact? Why or why not? b. What is the trust's fundraising strategy to achieve sustainable financing over the long term? How was it developed?	2. To what extent is the trust on track to reach administrative, operational, and financial sustainability? a. Did the trust establish a funding mechanism, such as Payment for Ecosystems Services, and obtain sufficient capital to sustain grant investments beyond the life of the compact? Is trust funding at originally planned or expected levels? Why or why not? b. What is the trust's fundraising strategy to achieve sustainable financing over the long term? How was it developed?
3. How did leaders of the implementing consortium use their organizations' experiences to establish the trust? a. What lessons did these leaders draw from their own grant-making experience that they applied to the establishment of the trust?	

Table A.1. ***(continued)***

Research questions – Interim report	Research questions – Final report
Overall ENRM project evaluation	
1. How has land use along the Shire River changed during the ENRM project?	
2. If the project activities were expanded throughout the area, how would the activities affect sedimentation in the Shire River based on alternative modeling scenarios? a. How would reductions in sedimentation affect hydropower production based on the alternative scenarios?	
3. Based on the results of each activity's evaluation, which implementation factors supported or hindered the effectiveness of the ENRM project overall? a. How did ENRM project implementation vary from what was planned, and why? b. How did these changes in implementation affect overall outcomes?	
4. Did the ENRM project achieve its targeted intermediate and final outcomes and contribute to higher-level compact objectives? Why or why not? a. Were there any unintended consequences of the program (positive or negative)?	1. Did the ENRM Project achieve its targeted intermediate and final outcomes and contribute to higher-level compact objectives listed below? Why or why not? a. Outcomes: i. Reduced siltation and weed infestation in the Shire River Basin ii. Increased efficiency of hydropower generation iii. Improved electricity reliability and increased power generation b. Compact objective: Reduced poverty through economic growth c. Were there any unintended consequence of the program (positive or negative)?
5. Based on the results of each activity's evaluation, what are stakeholders' perceptions of sustainability of outcomes achieved under the ENRM project, and why? a. What could or should be done to increase sustainability?	2. Based on the results of each activity's evaluation, what are stakeholders' perceptions of sustainability of outcomes achieved under the ENRM project, and why? a. What could or should be done to increase sustainability?

Appendix B.

Supplemental results for WSM Activity evaluation

Table B.1. Robustness checks for regression models estimating the effect of Liwonde weed-harvesting activities on total electricity not generated (MWh) because of weeds, by HPP

	Nkula				Tedzani				Kapichira			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Post	-342.049 (550.36)	-3.019 (424.59)	-754.373 (853.72)	-108.519 (401.96)	-135.66 * (73.05)	-83.551 (54.229)	-186.98 * (112.07)	-94.726 (59.893)	-225.768 (139.13)	-33.532 (79.650)	-333.499 (217.20)	-80.75 (81.99)
Time	4.643 (3.823)	3.208 (3.035)	6.079 (4.922)	3.451 (3.693)	0.467 (0.644)	0.403 (0.628)	0.644 (0.743)	0.413 (0.657)	1.060 (1.018)	0.060 (0.930)	1.430 (1.266)	0.183 (0.96)
Post x Time	-9.567 (9.033)	-0.778 (19.302)	-1.083 (13.362)	5.886 (21.616)	2.440 (1.892)	2.502 (2.034)	3.343 (2.335)	3.136 (2.643)	2.184 (3.015)	2.298 (3.166)	4.134 (3.920)	4.251 (4.55)
Constant	-437.798 (387.73)	-303.776 (275.73)	-2504.57 (2044.4)	-3252.03 (2503.9)	-6.257 (57.613)	2.877 (48.407)	-275.817 (266.28)	-267.451 (288.26)	-105.586 (100.22)	-33.822 (70.313)	-667.503 (538.79)	-843.1 (650.4)
Precip controls	X	X	X	X	X	X	X	X	X	X	X	X
Turbidity controls		X		X		X		X		X		X
Month FE			X	X			X	X			X	X
N	144	129	144	129	144	129	144	129	144	129	144	129
R2	0.078	0.351	0.132	0.439	0.058	0.364	0.110	0.413	0.090	0.414	0.135	0.462

Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: Robust standard errors are reported in parentheses. Each model includes contemporaneous and lagged monthly rainfall totals as measured at Liwonde using data from CHIRPS ("precip controls"). Models that control for contemporaneous turbidity levels at Walkers Ferry as well as contemporaneous and first lagged turbidity levels at Liwonde are denoted with "turbidity controls." Models including month of year fixed effects are denoted with "month FE." We count June 2018 as the start of the "Post" period, as the first full month following the May 2018 weed-harvesting equipment delivery. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021. Models that include turbidity controls have fewer observations because of missingness in water quality data.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Table B.2. Robustness checks for regression models estimating the effect of Liwonde weed-harvesting activities on total hours of electricity not generated because of weeds, by HPP

	Nkula				Tedzani				Kapichira			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Post	-25.974 (33.509)	-3.272 (26.561)	-49.406 (50.934)	-8.397 (25.063)	-9.756 ** (4.616)	-6.339 (4.084)	-12.877 * (6.571)	-6.873 (4.527)	-50.762 (43.689)	-15.306 (32.135)	-84.182 (68.841)	-24.171 (31.143)
Time	0.338 (0.240)	0.230 (0.186)	0.421 (0.302)	0.233 (0.229)	0.025 (0.050)	0.020 (0.054)	0.035 (0.054)	0.020 (0.055)	0.575 * (0.320)	0.423 (0.256)	0.692 * (0.407)	0.439 (0.303)
Post x Time	-0.704 (0.570)	-0.188 (1.182)	-0.215 (0.806)	0.201 (1.301)	0.177 (0.141)	0.095 (0.112)	0.228 (0.164)	0.126 (0.141)	-0.597 (0.683)	-0.076 (1.427)	0.084 (1.058)	0.469 (1.661)
Constant	-18.892 (17.992)	-12.253 (12.642)	-132.716 (116.01)	-186.146 (146.51)	2.301 (2.949)	2.880 (2.807)	-17.535 (14.348)	-12.868 (15.151)	-32.584 (24.436)	-23.267 (16.832)	-197.234 (156.49)	-259.779 (192.48)
Precip controls	X	X	X	X	X	X	X	X	X	X	X	X
Turbidity controls		X		X		X		X		X		X
Month FE			X	X			X	X			X	X
N	144	129	144	129	144	129	144	129	144	129	144	129
R^2	0.084	0.349	0.134	0.435	0.053	0.295	0.105	0.341	0.079	0.374	0.130	0.451

Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: Robust standard errors are reported in parentheses. Each model includes contemporaneous and lagged monthly rainfall totals as measured at Liwonde using data from CHIRPS ("precip controls"). Models that control for contemporaneous turbidity levels at Walkers Ferry as well as contemporaneous and first lagged turbidity levels at Liwonde are denoted with "turbidity controls." Models including month of year fixed effects are denoted with "month FE." We count June 2018 as the start of the "Post" period, as the first full month following the May 2018 weed-harvesting equipment delivery. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021. Models that include turbidity controls have fewer observations because of missingness in water quality data.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Table B.3. Robustness checks for regression models estimating the effect of Kapichira dredging activities on total electricity not generated (MWh) because of sediment, by HPP

	Nkula				Tedzani				Kapichira			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Post	-157.669 (202.386)	-242.058 (254.110)	-297.969 (306.417)	-455.800 (411.192)	-319.226 (265.054)	-335.513 (317.047)	-331.735 (272.017)	-352.372 (341.742)	-342.829 (233.164)	-367.013 (265.091)	-551.32 ** (264.325)	-476.719 (292.662)
Time	-1.699 (1.980)	1.207 (2.687)	-1.548 (2.395)	1.972 (3.352)	1.872 (2.785)	1.921 (3.082)	1.812 (2.646)	2.052 (2.947)	-3.381 (3.242)	-3.591 (3.685)	-2.935 (3.182)	-3.332 (3.413)
Post x Time	-1.804 (9.160)	38.573 (37.174)	8.671 (15.557)	56.963 (56.091)	-1.905 (2.512)	3.316 (8.881)	-0.748 (11.171)	5.402 (17.707)	1.520 (6.269)	22.940 (22.734)	20.222 (19.741)	31.895 (33.948)
Constant	151.380 (215.659)	-60.230 (279.461)	160.074 (1412.102)	-1361.420 (2187.937)	53.256 (127.939)	52.346 (152.998)	-296.893 (564.430)	-909.630 (931.495)	686.23 *** (255.235)	741.63 *** (282.264)	1135.485 (996.211)	193.186 (1959.455)
Precip controls	X	X	X	X	X	X	X	X	X	X	X	X
Turbidity controls		X		X		X		X		X		X
Month FE			X	X			X	X			X	X
N	144	129	144	129	144	129	144	129	144	129	144	129
R^2	0.059	0.337	0.099	0.413	0.016	0.022	0.070	0.092	0.075	0.153	0.121	0.214

Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: Robust standard errors are reported in parentheses. Each model includes contemporaneous and lagged monthly rainfall totals as measured at Liwonde using data from CHIRPS (“precip controls”). Models that control for contemporaneous turbidity levels at Walkers Ferry as well as contemporaneous and first lagged turbidity levels at Liwonde are denoted with “turbidity controls.” Models including month of year fixed effects are denoted with “month FE.” We count April 2020 as the start of the “Post” period based on the operations history of the Kapichira dredge. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021. Models that include turbidity controls have fewer observations because of missingness in water quality data.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Table B.4. Robustness checks for regression models estimating the effect of Kapichira dredging activities on total hours of electricity not generated because of sediment, by HPP

	Nkula				Tedzani				Kapichira			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Post	-11.122 (12.814)	-15.819 (15.653)	-18.040 (18.766)	-30.500 (26.226)	-31.371 (26.388)	-34.022 (31.308)	-32.382 (26.598)	-35.519 (32.678)	-70.649 ** (33.220)	-84.321 ** (38.979)	-88.773 ** (40.166)	-100.296 ** (47.263)
Time	-0.199 (0.151)	-0.016 (0.182)	-0.187 (0.168)	0.031 (0.212)	0.197 (0.276)	0.201 (0.305)	0.193 (0.262)	0.207 (0.293)	0.262 (0.339)	0.481 (0.377)	0.294 (0.338)	0.508 (0.400)
Post x Time	-0.001 (0.563)	2.604 (2.226)	0.493 (0.961)	4.119 (3.579)	-0.181 (0.246)	0.398 (0.710)	-0.073 (1.064)	0.660 (1.413)	-0.575 (0.764)	4.034 (3.108)	1.037 (1.995)	5.745 (5.058)
Constant	20.507 (15.304)	8.107 (15.477)	47.951 (91.028)	-60.480 (125.809)	8.901 (6.291)	9.422 (8.017)	-16.152 (44.440)	-57.471 (75.049)	17.252 (17.371)	12.391 (18.418)	47.985 (134.508)	-91.248 (188.635)
Precip controls	X	X	X	X	X	X	X	X	X	X	X	X
Turbidity controls		X		X		X		X		X		X
Month FE			X	X			X	X			X	X
N	144	129	144	129	144	129	144	129	144	129	144	129
R^2	0.058	0.315	0.090	0.389	0.015	0.018	0.073	0.091	0.052	0.296	0.115	0.394

Source: Mathematica calculations using data from EGENCO and CHIRPS precipitation data (Funk et al. 2015).

Note: Robust standard errors are reported in parentheses. Each model includes contemporaneous and lagged monthly rainfall totals as measured at Liwonde using data from CHIRPS ("precip controls"). Models that control for contemporaneous turbidity levels at Walkers Ferry as well as contemporaneous and first lagged turbidity levels at Liwonde are denoted with "turbidity controls." Models including month of year fixed effects are denoted with "month FE." We count April 2020 as the start of the "Post" period based on the operations history of the Kapichira dredge. Outcome values are summed across all machines operating at an HPP. N = 144 monthly observations for January 2010 through December 2021. Models that include turbidity controls have fewer observations because of missingness in water quality data.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Appendix C.

Additional information on Shire BEST's implementation

Table C.1 summarizes Shire BEST's achievements for each of the steps documented by Spergel (2015) as necessary in establishing an environmental trust.

Table C.1. Key steps and implementation results for the environmental trust

Key trust step	Status as of interim evaluation	Status as of final evaluation	Summary of implementation results
1. Establish trust steering committee	Achieved	Achieved	The trust implementers initially established a steering committee, which soon became the trust's board of directors.
2. Trust steering committee meets regularly until trust is legally established	Achieved	Achieved	The steering committee met while it was still the steering committee. The board also met a few times since its establishment, with members intending to meet quarterly. Because of scheduling conflicts, however, meetings, tended to be delayed.
3. Hire trust coordinator	Partially achieved	Achieved	MCA-Malawi initially contracted with a consortium led by Mulanje Mountain Conservation Trust (MMCT), which hired a trust coordinator to establish the trust. MCA later canceled the MMCT contract for nonperformance and hired a consultant to complete the work. The consultant's contract ended at the close of the compact in September 2018. One trustee, Doreen Chanje, volunteered to serve as the "trust coordinator," an unofficial position, until becoming CEO in 2019.
4. Develop name, mission, vision, programmatic focus, and objectives of the trust	Achieved	Achieved	These tasks were completed by September 2018.
5. Regularly coordinate/communicate with government stakeholders	Partially achieved	Achieved	The trust appeared to be in regular communication with several Government of Malawi ministries.
6. Draft trust legal documents (trust deed, articles of incorporation, constitution)	Achieved	Achieved	These documents were drafted by September 2018 and have not been updated since.
7. Legally register trust	Achieved	Achieved	The MMCT consortium completed this task in 2017.
8. Officially appoint trustees	Achieved	Achieved	The trust has a functioning board of nine trustees.
9. Hire trust executive director	Not achieved	Achieved	The trust's current CEO, Doreen Chanje, entered this role in July 2019.
10. Open trust bank accounts	Partially achieved	Achieved	The trust had opened a bank account prior to September 2019.

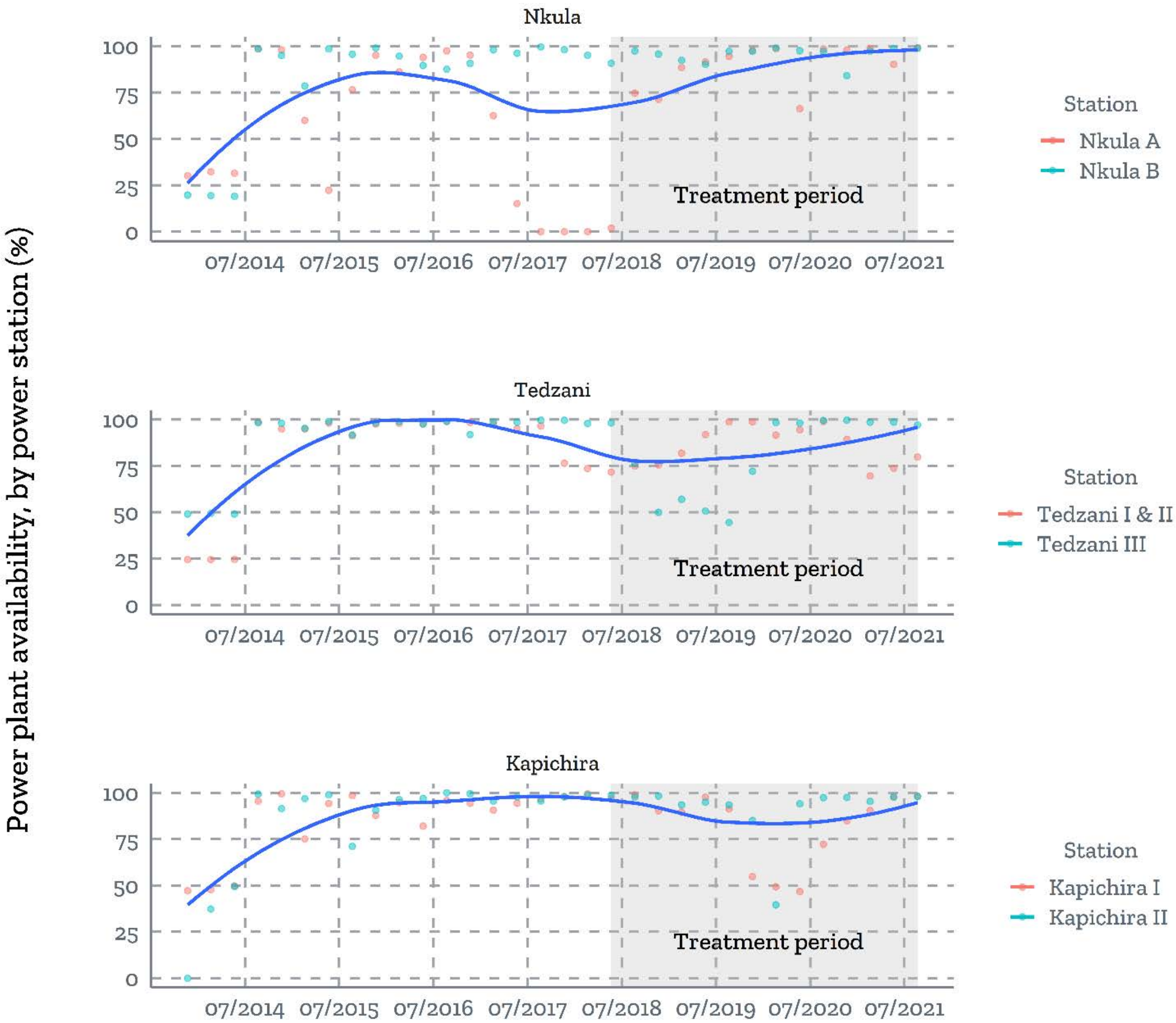
Table C.1. ***(continued)***

Key trust step	Status as of interim evaluation	Status as of final evaluation	Summary of implementation results
11. Obtain office space, equipment, and supplies for the trust	**Partially achieved**	**Achieved**	The trust currently occupies office space in the Shire River Basin Management (SRBM) Program building in Blantyre and has either inherited equipment and supplies from MMCT, which had been earmarked for them in compact documents, or has purchased necessary items for current-day operations.
12. Draft terms of references to hire permanent staff	**Partially achieved**	**Achieved**	TORs for current staff positions are available.
13. Approve an investment policy and investment guidelines	**Partially achieved**		No longer relevant, as the trust was not structured as an endowment.
14. Approve an operations manual	**Partially achieved**	**Achieved**	In September 2018, the consultant hired by MCA-Malawi developed a five-year strategic plan for 2018 to 2023, which covered trust management, funding, a strategic approach, and monitoring and evaluation. No updates have since been made.
15. Secure funding for the trust	**Partially achieved**	**Achieved**	Funds from the MERA-approved electricity tariff levy for environmental management were never received from EGENCO. Instead, EGENCO has provided two lump sum payments of 200 million and 220 million MWK. The trust continues to seek funding through a range of channels.
16. Hire an international investment manager	**Not achieved**		No longer relevant, as the trust was not structured as an endowment, which would have required a financial advisor.
17. Draft call for proposals, including grant application forms and reporting requirements	**Not achieved**	**Achieved**	Trust staff worked with the Board to draft a call for proposals.
18. Issue call for proposals	**Not achieved**	**Achieved**	A call for proposals was issued in local newspapers in 2019. Among the applicants submitting proposals, Training Support for Partners (TSP) was the sole grantee to receive funding.

Appendix D.

Supplemental results for overall ENRM Project evaluation

Figure D.1. Turbine-level availability by hydropower plant



Source: Mathematica calculations using data from EGENCO.

Note: The gray rectangle denotes the post-treatment period, which starts in May 2018 as the first full month of operations using the MCC-funded weed removal equipment. Availability measures the ratio of hours per month that a station is able and available to produce electricity against the total number of hours in that month. Loess smoothed lines (blue) are not adjusted for capacity differences across stations in an HPP. Turbine-level data were not available.

Appendix E.

MCC and stakeholder comments on draft report

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	xiii	Isn't the impact evaluation just for the WSM Activity?	The IE is not only for the WSM Activity, but also the Overall ENRM Project evaluation in which the ITS is applied to hydroelectricity outcomes summed across the three plants.
MCC M&E	xiv	Implementation Summary: Could you add relevant dates for the WSM Activity including delays on the dredge? For instance, state that the weed harvester became operational in May 2018, but for the dredge, not only was it delayed after compact close (Nov 2018), but wasn't utilized throughout 2019 due to issues with completion of the DMPA and other construction/operational issues (such as those detailed in post-compact monitoring reports). For the Executive Summary, this need not be as detailed, but do clearly state the time point where the dredge became operational (and regarded by the evaluation as the onset of the post-treatment period -- I see this is June 2018 in considering the weed harvester and dredge jointly). Also, as a general note, the word "compact" only needs to be capitalized when the report refers to the **Malawi Compact** (essentially treating as the 'name' of the compact). Otherwise, "the compact" need not be capitalized throughout the report.	We have updated the Executive Summary with more information about the operational timeline of both the weed harvesters and dredge. We have removed the capital case of "compact" except in instances that are appropriate based on your guidance.
MCC M&E	xiv	This reads a bit awkwardly. The environmental trust establishes… itself?	We have reworded this sentence to make it less awkward.
MCC M&E	xv	Figure ES.2: Can the figure specify that these are monthly volumes (and days of active dredging *per month*)? It's not clear / explicit.	We have updated the figure to make the timescale clearer.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC ESP	xv	Sediment Caused power losses: Completely agree with Mathematica that the reduction in losses to zero cannot be attributed to our program since our sediment efforts focused more on Kapachira with the dredge and the small grants and Trust work are too preliminary/small-scale to change the sediment loads. I find the result reported by Egenco interesting. BTW, there is the eventual risk that sedimentation may reduce because much of the easily erodable sediment has already eroded. I do not think Malawi is to that point, but it may become more like Haiti where sediment loads have reduced only due to having less sediment or coarser material that does not travel as far except for extreme events.	We would have liked to probe this aspect of the evaluation further, but delays in receiving data made it infeasible to conduct follow-up interviews to examine the results of our data analysis.
MCC M&E	xv	Can the figure specify that these are monthly volumes (and days of active dredging per month)? It's not clear / explicit.	The y-axis labels and the figure caption have been updated to clarify these are monthly values.
EGENCO	xvi	Funding for Shire BEST was envisaged to come under Payment for Ecosystem Model - whereby water users would be contributing into e.g. power generation, water boards, irrigation, hospitality industry etc	We have updated the ES to reflect that a PES model was considered early in the project and also provided this information in Section V.A.
Shire BEST	xvi	Funding the Trust with the electricity levy was Plan B. The original plan, which was the justification for establishing the Trust, was that MCC would provide an Endowment to kick-start the Environmental Trust….along with offices and other assets. I think it was $4m endowment or thereabouts. When this plan fell-through, thats when the idea of the electricity levy came in….but it was really very late in the life of the MCC project and it was not followed through and implemented. I think this part of the story should be included in this evaluation report, otherwise placing emphasis on the failed issue of the electricity levy, presents an unbalanced picture. On the premise that Evaluation reports should provide lessons, then I think we should include this full picture.	We have added some additional detail about those funding discussions and the timeframe to better contextualize the trust's funding status.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
Shire BEST	xvi	This figure should be revised downwards, to reflect the actual funds that have been disbursed to Shire BEST. In MKW, the total amount disbursed is MK255million. EGENCO has not disbursed MK165m, and we are not sure that these funds will be disbursed. 2. During the last week of April 2022, after lengthy negotiations, Illovo Sugar Company approved to support Shire BEST with MK66million for a 1 year period. This support will cover 25% of Shire BEST Administration budget, with the rest of the funds going towards the community interventions. The support is for a FLOOD Protection project in a community surrounding the sugar Estate, in Chikwawa District. Illovo draws its irrigation water from the Shire River, and is one of the key stakeholders in the Shire Basin. This funding is a significant development and demonstrates that key private sector companies are assured that the Governance structures in Shire BEST are robust enough.	We have incorporated information into the ES as well as in the main text.
MCC ESP	xvi	Trust PES: the amount contributed by the stakeholders is depressing. Even without the official levy approved, amounts were built into the tariff application. Both EGENCO and ESCOM were approved for those amounts. However, because the tariff was approved at a lower level than anticipated, I am sure that both agencies have canibalized the approved levels. Plus ESCOM never came forward with the amount it was supposed to provide under the PES. Not a comment for action, but just a clarification that even without the levy (which required an act of ministers to approve) there was an amount in the tariff application.	We have inserted a footnote describing the approved tariff increase and the possibility that ESCOM/EGENCO directed funds that were requested to support Shire BEST to themselves instead.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	xvii	Can you add a footnote to briefly describe the activities/interventions supported by the WB Shire River Basin Management Program? As I recall, it was similar in nature to the ENRM grants focusing on upstream land use / land management by farmers. But if similar in scale to the ENRM grants, how plausible is it that the program realistically influenced sedimentation in the river? Figure ES.4: Can you clarify in the figure heading or notes that each graph reflects total MWh and hours aggregated across the 3 HPPs - Nkula, Tedzani, & Kapichira? This isn't explicit in the figure -- same point for noting that MWh and Hours are per month. Lastly, the figure notes that June 2018 is regarded as the start of the treatment period, but in the detailed results will you explore the start of dredge operations vs. weed harvesting separately? The former came (presumably) at least 18 months later or thereabouts (please confirm).	We have added a footnote in the ES to describe the key components of the World Bank project. We have also added a paragraph in Section III.B.6 to clarify the role the SRBMP plays as a potential confound in our analysis, explaining that its activities covered a relatively small footprint in the basin and is therefore unlikely to be the dominant explanation for changes in HPP performance. We have updated the subfigures and the figure title (now this is Figure ES.5) to more clearly reflect the timing and that it encompasses all three HPPs. That is correct - we use the respective start times of weeding and sedimental removal activities. When examining total effects, a single treatment start date has to be chosen and we have opted for the earlier date (when the new weed harvesters began operations). Had we chosen the later start date (when the dredging equipment became operational), then timesteps where the WSM activity was in operation -- because the weed removal equipment was active -- would falsely have been identified as part of the pre-treatment period.
MCC ESP	xvii/xviii	Electrical capacity: Glad to see the project exceeded targets for available capacity. As I mentioned on a call, this evaluation was done before Cyclone Ana. Kapachira had a dam wall breach and is completely down, and both Nkula and Tedzani suffered damage. It was an extreme event, but it demonstrated the threat of climate change (future extreme events) and the fragility of the system.	We completely agree and thank you for the comment. We hope that future donor investments can improve the sector's resilience, given the economy's reliance on a small number of generation units.
MCC M&E	1	Any reason the capacities listed in the footnote sum to 347 MW, whereas the text below states 386?	We have updated the capacities using values reported by EGENCO, which now also sum to 386 MW.
MCC M&E	2	Can you refer to the objective in the program logic section?	We have updated the opening sentence to clarify the ENRM's objective.
MCC M&E	2	Why does this list start with (d)?	We have updated the formatting to correct this.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	3	"The theory of change also reflects the potentially bidirectional relationship between certain outputs and outcomes denoted by double-headed arrows." As noted for the Volume I report, there is some inconsistency with how MCC defines outputs vs. outcomes, where outputs are the activities, services, or goods/materials directly provided or implemented by grantees or other implementers, meaning there could not be a 'bi-directional relationship' with outputs that are funded or delivered by the compact -- therefore in the logic, 'Adoption of sustainable land use practices' would clearly be defined as a (short-term) outcome rather than an output. There may indeed be a bi-directional relationship as depicted, but the Adoption result is improperly classified as an output.	You are correct - we have updated the TOC diagram and shifted "Adoption of sustainable land use…" as an outcome, along with "Sustainable funding for the trust" and "Establishment of trust."
EGENCO	5	It should be mentioned that 4 tipper trucks were procured under WSM - 2 each for Liwonde and Kapichira	We have enumerated the specific number of pieces of equipment funded through the compact in Chapter IV.
MCC M&E	6	Re: charcoal production -- wouldn't it be more accurate to say it contributes to deforestation than excessive land use?	We have reworded this sentence.
MCC M&E	6	Wouldn't it be more accurate to say it contributes to deforestation?	That is correct - we have updated the text accordingly.
EGENCO	7	It should be stated that the split between ESCOM and EGENCO was effected in January 2017 upon review of the Act	We have included this information in the relevant footnote.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	7	WSM Implementation Summary: "Although the weed harvesting equipment was delivered and operational before the Compact ended, delays in procuring the dredge meant that dredging activity did not actually begin until April 2020, when EGENCO and MCA-Malawi's follow-on agency—the Malawi Millennium Development Trust (MMD)—stepped in." Please provide more of the relevant detail here, even just briefly, on the reasons why dredging didn't begin until April 2020 -- in particular noting that while the dredge itself was delivered in Nov 2018, works on the sediment disposal area and other issues remained unfinished throughout 2019. Even a brief summary of these further issues/challenges in the post-compact period would be useful to document here.	We have added text about the various tasks that preceded active dredging in a revised version of this subsection.
MCC M&E	10	The summary here states that "[i]n practice, grantees targeted male and female farming community members within selected villages because they were the **most likely to be able to implement and benefit** from the activities" but also goes on to mention that "Most of the villages selected by grantees were located in or near "hot spots" as suggested by the Middle and Upper Shire Baseline Assessments and Action Plan... indicating that grantees were successful in targeting their programming in the areas of **highest priority for catchment restoration activities.**" Isn't it primarily the fact that participants ***resided in*** those priority hot spot areas that determined their selection for targeting of grant activities? It's not clear what is really meant by suggesting they were "more likely to be able to implement" the activities than an unknown alternative group of participants -- or why those targeted would be 'more likely' to implement activities than others. Please clarify or explain.	Thank you for that suggestion. We have reworded this section to reflect that participants from those hot spots were selected based on whether they were actively working in agriculture.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC ESP	10	Re-procurement of the Trust Cooperative Agreement: The first procurement was a bit more complicated. We got one bid from MEET during the first bid. We ran the procurement in August when most European organizations were on leave. We heard there was interest in more organizations in bidding, but the timing did not work. We canceled the procurement and re-procured. Curiously, we still got one bid, but this time it was the consortium we hired through the Cooperative Agreement. It included MEET as a sub under Malange Mountain Conservation Trust along with IUCN and WCS. Another interesting fact: after the Cooperative Agreement was signed, we learned that Malange Mountain Conservation Trust had not formalized the partnership agreement with MEET, IUCN or WCS. This contributed to yet more delays as it took a few months to finalize these partnership agreements.	We have added these details to the trust's implementation description.
MCC M&E	10	Same comment as in previous section – this seems awkwardly circular / self-referencing.	We have reworded this sentence to make it less awkward.
MCC M&E	16	The report indicates that sediment management activities at Kapichira “began only with the arrival of the new dredging equipment” -- although realistically, the equipment arrived in Nov 2018 but an additional year or more transpired before the sedimental disposal area was completed, so really the dredging got underway only by 2020.	We have updated the text to better communicate the purpose of that statement: Unlike weed removal at Liwonde which was in place prior to MCC's support, there was no dredging at Kapichira until the WSM equipment became operational.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	19	"By independently analyzing Kapichira, we can test whether the dredging activity affected only that HPP." Might this say whether dredging ***specifically*** affected Kapichira? Of course it would ***only*** affect this HPP since it's downstream of the other two – but the presumption here is you're trying to isolate whether dredging specifically (vs. dredging and/or weed harvesting combined) affected Kapichira.	We think that "only" is the correct word since we are not in this section comparing the effects of dredging and weeding on plant performance, but the effect of dredging across each of the 3 HPPs (since we have outcomes data for each). If Kapichira is the only HPP showing a reduction in silt-related losses, then this would validate the claim that it was due to the dredging. Conversely, if all of the HPPs register reduced silt-related losses, then the WSM dredging activities cannot be single-handedly responsible for the reason you mention: the flow of the river dictates that dredging at Kapichira should only benefit Kapichira. By proceeding in this fashion, we can test whether there are non-dredging factors that contributed to silt-related losses affecting the HPPs.
MCC M&E	20	And also the specific contribution of dredging vs. weed harvesting, no?	Since EGENCO provided data that separately reports out weed- from silt-related hydropower plant performance, we don't have to disentangle the individual contributions of the weed harvesting efforts from the sediment management. The only concern would be if weed removal has some effect on sedimentation, or sediment removal has an effect on weed infestation, and we do not believe there is any support for such a claim.
MCC ESP	21	Key results: just a heads-up, we know that the pipeline broke loose from its moors during cyclone Ana, but we do not know what the damage is to the dredge or if it was damaged from the storm and flooding. It will be interesting to see how quickly EGENCO can get things operational again. No news on the harvester or other equipment upstream at Liwonde.	Thank you for sharing this update about the equipment status. Hopefully these issues were transient and EGENCO has been able to get back to full capacity with their WSM activities. We have included a footnote in IV.B about this impact from TC Ana on Kapichira performance.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC ESP	21	Sustainability: MCC provided additional spare parts beyond the manufactor's recommendations. Ellicott more or less double the traditional spares provided with dredges. Has EGENCO already used the spares? Is this due to normal wear and tear or operator usage?	We do not have a very precise answer to this question. During our July 2021 site visit, EGENCO staff had given the impression that the spare parts that were on hand at that time were from the recently filled Aquarius order, which suggests that they had indeed used all the MCC-provided spare parts. The packing slip we were able to photograph indicates at least two dozen distinct parts required for harvester operation. We did not conduct an inventory for the number on hand relative to the number ordered during that site visit.
MCC M&E	22	The heading for Section A here seems to be unmatched with the subsections described in the paragraph that follows. Why is the heading focused (only) on weed-harvesting when these subsequent sections listed below also deal with dredging? The numbering in the paragraph (e.g. 'A.2, A.3, A.4') also suggests that whatever falls under Section 'A' should cover both the 'W' (Weed) AND 'S' (Sediment) pieces – i.e. the whole WSM Activity. Also, for Section IV.A4, what about sustainability of weed harvesting results (in addition to dredging)?	We have updated the text to reflect that all A-lettered sections are exclusively dealing with weed harvesting. We have amended the text to reflect that this subsection refers to the sustainability of weed harvesting activities.
MCC ESP	26	Nutrient Load: Weed growth is rather complex. Initially, MCC made a similar case for nutrient loads driving weed growth. However, even without nutrients from soil erosion, there is a lot of nutrient cycling in the river from existing sediments, weed decay and other plant materials. From the weed studies done during development, the critical issue was the location and continual growth of weed nursery areas upstream from Liwonde in the lagoons. There are so many weeds and nursery areas that it is quite likely that weeds will be on an ongoing basis. Plus, as mentioned in one place in this report, poor management of the weed harvested allows seeds and weeds to re-enter the riverine system. Plus, seeds remain viable for years.	That is a very helpful comment - we have caveated the statement about the rainy season's role in weed formation in the main body, and inserted a footnote to describe the weed nursery sources that could be the source of "out-of-season" accumulation.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	28	Does the expenditure on weed removal values take inflation into account? On page 33, you state that inflation has been 16.5%. If these are nominal values, the real increase in costs may be more modest.	The weed management expenditures are inflation-adjusted and presented in 2017 MWK. Although annual inflation averaged 16.5% over the 2011-2020 period, in this figure we use annual inflation rates reported by the World Bank.
MCC ESP	30	Downtime: May not be able to determine a level of attribution. However, just to note that in addition to the harvesters at Liwonde, MCC installed new trash rakes and cages around the turbines at Nkula. It would be interesting to know how much weed is collected at Nkula because that may speak to some of the impact of the harvesters upstream at Liwonde and how much is stopped by the new cages and trash rakes around the turbines at Nkula (Note that Tedzani is only 9 KM south of Nkula and may only have weeds that flow through Nkula - though very likely that some weeds are growning between the two power plants).	We have included the purchase of the small trash barriers at the Nkula HPP on page 24. On page 30 we have included a caveat for interpreting results that there is the attribution problem you describe, but claim that the magnitude of weed removal differences between Liwonde and Nkula makes it likely that the Liwonde harvesters are primarily responsible for any weed-related electricity performance improvements. We unfortunately did not receive any data from EGENCO about weed removal at Nkula, so are not able to assess the relative contributions of changes in HPP outcomes between the Liwonde equipment and the Nkula equipment.
MCC ESP	33	Spare Parts: MCC provided spare parts for the harvesters as well. Has EGENCO already used all the key spare parts that were provided?	We do not have a very precise answer to this question. During our July 2021 site visit, EGENCO staff had given the impression that the spare parts that were on hand at that time were from the recently filled Aquarius order, which suggests that they had indeed used all the MCC-provided spare parts. The packing slip we were able to photograph indicates at least two dozen distinct parts required for harvester operation. We did not conduct an inventory for the number on hand relative to the number ordered during that site visit.
MCC M&E	33	The issue of spare parts not being available seems to be a consistent issue across infrastructure. Not for MPR response, but noting for possible learning	Agreed. Thank you.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	33	How does this finding on spare parts square with the observation on p. 28 that EGENCO staff 'stated that there has been no significant equipment downtime, and they have had spare parts to replace equipment as needed."	Our understanding is that this recent parts delivery from Aquarius may have coincided with the exhaustion of at least some spare parts in their inventory, illustrated in the quotation on page 34. If this correct, there was no equipment downtime and for some period of time there may have been no spare parts on hand (for some components, not necessarily across the board for all parts). The arrival of the parts, when it happened, may have averted a forced shutdown. Assuming this is an accurate depiction, we do not know the duration over which any spare parts were momentarily unavailable had the need arised.
EGENCO	34	Attributes delays of Kapichira dredger due to cancellation of Nkula dredger in the package. This should be reflected on page 7 Section D.	We have incorporated this information into the implementation summary.
MCC ESP	34	Bundled Procurement: We did get a middleman agency to respond to the bundled dredge and harvester procurement (against MCC's recommendations against bundling). JGH, though, was partially terminated for dredge portion of the contract after a long, painful contract dispute. It is complicated, but I am willing to provide details. There is a whole case study of this termination done by MCC's external counsel that helped with the termination and eventual negotiated agreement with JGH. Very complex situation poorly managed by the project manager at the MCA.	Thank you for that. We have included this information in a footnote in Section IV.B.1.
MCC M&E	34	I had thought this stood for 'dredged material placement area' – same difference I guess.	We have updated the text to "disposal management placement area" after re-reviewing EGENCO's Commissioning and Sustainability Plan (pg. 31). In the Star report, "dredged material placement area" is used.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC ESP	35	Overheating of the Dredge: We initially suspected that the overheating was due to some of the specs that Fichtner had included for emissions abatement under EU requirements, but in tropical countries, it can lead to over heating. Do you have any details on the coolant tank and why it was needed? Was it wrongly speced? I still have the email of the consultant that we used from our independent engineer, who is an expert in dredges. He may be able to provide more background (and would willingly give us more background in what went wrong).	You are right that the tropical environmental conditions can lead to engine failures because the heat and humidity can affect dredges' computerized fuel pumps. We followed up with engineering consultants involved during the compact and learned that the overheating issue was partly because of the EU emissions controls and partly because a booster pump that was included in an earlier version of the dredge design was not included in the actual delivered dredge. The consultants did not receive an explanation from Fichtner for why the booster unit was removed from the dredge specifications. It is possible that the booster cost was a factor for its removal. We have added more detail to Section IV.B.1.
MCC M&E	35	I seem to recall it was received just after the compact ended (Sept 2018), but still during the closure period – around Oct/Nov 2018.	EGENCO staff shared that offloading of the dredge equipment began on 9/29/2018, and so we have updated the text to reflect that it was delivered shortly after the compact ended.
MCC M&E	36	Is it possible for the timeline to be linear in the graphic rather than in a circle? The circle makes it feel like a feedback loop.	We have updated the timeline to now be in a linear format.
MCC M&E	36	Re electric vs. diesel dredge, one wonders what the cost of constucting a substation with a transformer to power an electric dredge would have been relative to diesel fuel costs over a given amount of time, and why EGENCO wouldn't have considered the trade-off accordingly.	We are not aware of any cost comparisons examining the total discounted cost of the substation versus the diesel fuel. We agree that such a comparison would have been helpful in informing EGENCO of which was the more affordable option over some given time period.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC ESP	37	Sediment removal: Engenco's plan to remove all the sediment is frankly not economically viable. Plus, Fichtner estimated a re-sediment rate of 220,000 MT of sediment per year. Maintenance dredging would be needed yearly to maintain the active storage. According to the Fichtner plan, this could be done during the rainy season running the dredge 24/7 for four months (not realistic, but it would have been able to do the dredging without expanding the disposal area - DMPA - as the rainy season discharge would allow for river discharge for maintenance. Plus, if Egenco wanted, they could move the dredge to other HPPs, assuming they had disposal during the dry season dredging. Does this mean that EGENCO's dredging at Kapachira did not focus on the capital dredging portion to restore active storage? Were they just dredging in a haphazard way, or was there a systematic approach to their dredge operation?	We do not have a complete answer to this. We did not receive any information from EGENCO about where in the reservoir dredging activities took place, only the volumes of dredged material. We also did not observe any maps in EGENCO's Commissioning and Sustainability Plan to indicate where in the head pond dredging would be concentrated. EGENCO staff did not discuss the prospect of transporting the dredge elsewhere, but rather gave the impression the equipment would exclusively be used at Kapichira.
MCC ESP	38	DMPA: Given that EGENCO has exceeded their dredging targets, it is not surprising that the DMPA is full. It was designed for the capacity based on FIchtner's plan for capital and maintenance dredging. Space for dredging disposal may be the next challenge that Egenco faces.	We agree and particularly hope that the preferred dredging site has minimal to no adverse social and environmental impacts.
MCC ESP	39	Clutch problem: Is that user error? Or, is it over-use? Defects?	This is an open question that we do not know the answer to.
MCC M&E	39	Vertical axes should clarify monthly	The y-axis labels and the figure caption have been updated to clarify these are monthly values.
MCC ESP	40	Dredge efficiency: Our dredge expert said that efficiency may be hurt by operators not lowering the suction into the sediment, but keeping it slightly raised. It could operate faster, but more water than material was being pumped through the dredge.	This is helpful information. We did not ask EGENCO operators about how they were operating the dredge, although this would have been helpful.
MCC M&E	41	Can you state the $ value as well as the MWK value in the bolded topic sentence?	We have added the USD equivalent in the topic sentence.
MCC M&E	42	Chart title should say ‘Total monthly sediment management costs’	Figure title has been updated.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC ESP	43	If the Nkula DMPA is reaching the end of its useful life, what is the long-term plan? Sedimentation will still be an issue, and Egenco does not have much space for disposal.	We briefly discuss this on page 50. EGENCO reports that they have begun land survey operations to identify another disposal site, but there were no finalized details about the specifics or the timing that were shared with the evaluation team.
MCC M&E	45-46	Figure IV.14: What can explain the proportionally large drop in generation losses at Tedzani, given it's upstream of Kapichira -- and especially, why would the timing of the drop coincide with the start of dredging at Kapichira? Same question goes for Tedzani in Fig. IV.15 on hours of HPP downtime due to sediment.	That is right -- we briefly addressed this on pg. 45-46, and have added some additional text which reinforces existing text from the evaluation methods section (pg. 20-21, “To examine whether Activity benefits varied by location, we estimated impacts separately by HPP, because factors related to their upstream and downstream placement necessitated independent analyses. For example, we assessed outcomes at the Kapichira site separately from Nkula and Tedzani because the WSM dredging activity at Kapichira should have no operational effect on the upstream HPPs. By independently analyzing Kapichira, we can test whether the dredging activity affected only that HPP, whereas combining outcomes of all HPPs into one measure would obscure the location of any estimated changes.”) In brief, the answer is not clear. As we mentioned in the report, the improved HPP performance does not in fact perfectly coincide with the start of dredging operations -- it is quite possible that whatever factor is responsible originated in 2018, when a downward shift appears in both the electricity generation losses and the hours of downtime figures. Unfortunately we received the data from EGENCO too late in the evaluation window to be able to conduct follow-up interviews with stakeholders who might be able to offer an explanation for this finding. An alternative explanation rests with the quality of EGENCO reporting data, and the possibility that silt-related losses data that we received suffer from some type of systematic inaccuracy.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	46-47	Should it be noted in the text that the regression results for 'Post' (i.e. a post-treatment effect) are not statistically significant? How should the apparen changes in trends shown in the ITS analysis be interpreted in light of this?	We have added a paragraph on page 32 that addresses this concern and provides an explanation for why the estimates with large magnitudes can only be noisily estimated. We do not believe this should detract from the findings offered by the point estimates.
EGENCO	49	On Shire BEST funding, wasn't MCC supposed to pump in a starter-pack amount. If so this need to be mentioned and indicate why it did not materialise	We have now included the rationale for why MCC could not support an endowment model.
MCC ESP	49	Key findings: ESCOM was also supposed to provide part of the PES funding from the tariff. The proposal broke it down 75% for Egenco and 25 for ESCOM (as the impact was more critical on EGENCO's operation, so they may have more interest in paying for better land management). ESCOM never paid anything. The percentage comparing what Shire BEST received from EGENCO compared to what was proposed is depressing.	We agree that the received amount is a giant shortfall relative to what was proposed. We have added text in the key finding to make clear that ESCOM would have been a co-contributor of funding to Shire BEST had the funding model advanced. We have included the 75/25 relative responsibility in edited text on page 53.
MCC M&E	49	Please be sure to refer to ESCOM's planned commitments per the tariff / levy (as noted in the comment above).	Please see preceding comment.
Shire BEST	49	In the summary table below……please include that Illovo has confirmed that they will support Shire BEST with MK66m for 1 year. This will cover 25% of Administration costs, with the rest of the funds going towards direct project interventions in the Lower Shire, Chikwawa district. This demonstrates that private sector is willing to support Shire BEST, and such support can be used to leverage with other potential donors. This support from Illovo also shows that stakeholders have confidence in the governance and accountability systems within Shire BEST	This is great news and we have included new text describing this update.
Shire BEST	51	We have not managed to get any confirmation on this, despite several attempts to do so. If during the course of this evaluation you have come across this information, we would greatly appreciate if you were able to share or point us in the direction to get such confirmations, because it has a significant bearing on our way forward.	The findings in the report are the best information we have been able to obtain from our data collection.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
Shire BEST	52	Actual funds disbursed under this MOU totaled MK55m. The MK165m has not been disbursed todate, and Shire BEST funds dried up in February 2022.	We have updated a footnote with this information.
MCC M&E	52	Just to clarify, was the 2nd MOU amount of $273,000 actually disbursed to Shire BEST?	Shire BEST informed us after receiving the draft version of this report that they received approximately $68,000 under the second MOU, not the $273,000 that was listed in the MOU. We have added a footnote describing this on page 54, noting that the financial statements confirming this are not yet available.
MCC M&E	53	Why was the trust forced to terminate the TSP grant? Was it performance of the grant or the need for the funds to be used for operating expenses?	We have clarified the text to reflect that it was terminated in order to reappropriate funds to cover its own operating expenses.
Shire BEST	54	Malawi Government, through the Environmental Affairs Department, has since written a Letter of No Objection to the IUCN, for IUCN to support Shire BEST in reviewing and submitting the proposal to the GCF. This is a significant development, because it demonstrates that Government is aligned with the Draft Proposal. The Department of Water has also endorsed the draft proposal and would be the Lead Government Department in this GCF proposal.	Thank you for sharing this information with us. We have included this information in Section V.A.
Shire BEST	54	Illovo has now confirmed that they will support Shire BEST with K66m for 1 year on this project. 25% of Shire BEST Admin costs would be covered under this financing support.	This is very good news - we have included this information in a new footnote.
MCC ESP	55	Organizational capacity: MCC had encouraged MMCT to take over the small grants portfolio in the second and third year, so that they could claim organizational capacity. MMCT did not want to do that. Plus, at the time, they did not have the capacity to manage (2nd year) and by the 3rd year questions of fraud were coming to light. We were aware this would be an issue, which is why we proposed that Shire BEST take over the small grant pilot program.	Thank you for this - we have added this information in Section V.A in the finding related to whether Shire BEST would be an effective vehicle for funders' resources.
MCC M&E	55	Where is Table C.1 - am I missing it?	We have relabeled this as “Appendix Table C.1” to make it clearer that the table is in the appendix section.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC ESP	59/60	Turbidity: Hard to see how any of MCC's interventions impacted turbidity. The grants were too small. Dredging will lead to site specific increases in turbidity. The Trust is not really operational. Long-term, if all these things are expanded, then you may see some results in water quality. There is also a lag time with turbidity as the river would have a legacy flow of sediments that have accumulated in the channel, likely to be transported when there are extreme events but which also get deposited along the river. It is unlikely that the sediments would be too reduced due to MCC and WB interventions. It would be interesting to see if there are intervening factors like seasonality or rain events (fewer) that can explain why the turbidity may be showing these results.	We have removed this section from the final report version.
MCC M&E	59-60	The report doesn't really clarify how or why there would be a relationship between WSM interventions and color or turbidity, even at the Walker's Ferry/Nkula location. Only weed harvesting takes place upstream of Nkula (at Liwonde) -- but does weed removal have any impact on or relationship with either water quality indicator? Meanwhile, dredging only takes place at Kapichira, downstream of any of these monitoring stations -- and even the previous dredge at Nkula could only cause site-specific increases in turbidity, as noted in the comment above. Therefore, what is/was the theorized effect of WSM interventions in any scenario? This section could be more clear on this point.	We have removed this section from the final report version.
MCC ESP	63	Outage reductions and efficiency: I can appreciate the WB funding reducing outages. The new turbines at Nkula should be more productive. Plus, we did install new weed cages and trash rakes to reduce some of the outages from weeds at Nkula at least.	That is right -- we believe there were likely to be synergies between MCC's and the World Bank's investments.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	64	Should any comment or observation be included on how none of the regression results appear to be statisically significant at the 0.05 level?	We have added a paragraph on page 32 that addresses this concern and provides an explanation for why the estimates with large magnitudes can only be noisily estimated. We do not believe this should detract from the findings offered by the point estimates.
MCC M&E	65	Specify that these are monthly data.	The y-axis labels and the figure caption have been updated to clarify these are monthly values.
MCC M&E	66	"The troughs in availability at Nkula and Tedzani (and therefore also in the "All HPPs" panel) that preceded the treatment period suggest that availability levels would have further decreased in time had the ENRM Project not taken place." For Nkula, are you certain the lower availability wasn't associated with ongoing construction on the Nkula A portion associated with the Infrastructure Development Project?	That is a very fair point - in reviewing the data, the trough for Nkula is caused by availability levels of 0% for Nkula A for parts of 2017/2018 which would reflect the rehabilitation works. We have updated the text to address this and dropped language claiming that Nkula availability would have continued dropping (which we reserve only for Tedzani).
MCC ESP	71	Bathometric survey: MCC purchased a survey boat. Why has a bathometric survey not been done? That was the whole point of that boat. Plus, the dredge also has some sonar equipped survey equipment onboard. It may not be as accurate as the survey boat, but it would be able to gather some data. I suspect that EGENCO is not very systematic about their dredging and not using the survey equipment to guide their work systematically.	One EGENCO interviewee stated that a bathymetric survey would be conducted later this year, but no interviewees discussed the use of a survey boat to guide the location of dredging activities. Few if any other respondents mentioned the boat or survey equipment.
Shire BEST	72	Need to change this to reflect actual funds received by Shire BEST, which is less than $550,000	We have modified the wording to not indicate that funds of that scale were received.
MCC M&E	72	WSM Question 5, Key Finding #2 -- on EGENCO's continuing WSM removal activities, you might consider adding to this – *and will need to identify additional areas for sediment disposal.* This seems to be another sustainability risk for the activity. For ENRM Trust Question 2, on the TSP grant -- mention the early termination?	Thank you - we have added those text edit recommendations.
MCC M&E	72	Might consider adding to this – and will need to identify additional areas for sediment disposal	Thank you - we have added that text.

MCC and stakeholder comments *(continued)*

Reviewer Institution / Role (e.g. DCO, GSI, EA)	Page number	Comment	Evaluator response
MCC M&E	72	Doesn't this also include financial sustainability?	We have included financial sustainability into the RQ text.
MCC M&E	72	Mention the early termination?	We have added text regarding the early termination of the TSP grant here.
MCC M&E	73	Just observing that the key finding / research question on unintended consequences was addressed on p. 69 but these issues were not flagged there; the report only stated that "Interviewed stakeholders, secondary data, and related documents do not indicate there were any material unintended consequences, either positive or negative." I suggest adding these points there.	These items were an oversight and have since been removed from this section.
MCC M&E	73	Just observing that this same research question (on unintended consequences) was addressed on p. 69 but these issues were not flagged there; only stating that "Interviewed stakeholders, secondary data, and related documents do not indicate there were any material unintended consequences, either positive or negative."	These items were an oversight and have since been removed from this section.

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