LASER PULSE

Long-term Assistance and SErvices for Research (LASER) Partners for University-Led Solutions Engine (PULSE)

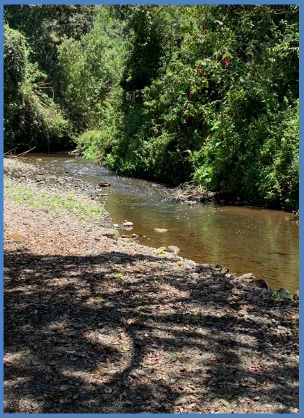

Photo: Sasumua River Watershed headwaters.

Photo credit: Margaret Gitau, 2021

Data-Driven Decision Support for Improved Water Security in East Africa

FINAL REPORT

SUPPLEMENT TO AGREEMENT NO. AID-7200AA18CA00009

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July 31, 2023

ABOUT THE PROJECT

The LASER PULSE East Africa Water Security project aims to provide water information, data access, and decision support to improve water resources (quantity, quality) management and, ultimately, water security in East Africa. Case studies have been conducted in three key watersheds—representing a variety of climatic and landscape regions, and threats to water security—using a combination of existing climate data, recently developed rainfall data, and a modeling approach. This document is intended for use by researchers, practitioners, and water resources managers. Products described herein, along with products accessible through companion resources provided, can be used in a variety of water resources applications. In particular, these products are important for use with hydrologic and water quality modeling, and to inform water resources decision making and management in general.

PROJECT PARTNERS

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ABOUT LASER PULSE

LASER (Long-term Assistance and SErvices for Research) PULSE (Partners for University-Led Solutions Engine) is a $70M program funded through USAID's Innovation, Technology, and Research Hub, that delivers research-driven solutions to field-sourced development challenges in USAID partner countries.

A consortium led by Purdue University, with core partners Catholic Relief Services, Indiana University, Makerere University, and the University of Notre Dame, implements the LASER PULSE program through a growing network of 3,000+ researchers and development practitioners in 74 countries.

LASER PULSE collaborates with USAID missions, bureaus, and independent offices, and other local stakeholders to identify research needs for critical development challenges, and funds and strengthens the capacity of researcher-practitioner teams to co-design solutions that translate into policy and practice.

ACKNOWLEDGEMENTS

David Mugenyi (Makerere University); Okoko Kassam, Chrisoggonous Peter (University of Dar es Salaam); Lusekelo Kibanda, Frank Anderson (GWPTZ).

CITATION

Gitau, M.W., V.M. Garibay, N.S. Kiggundu, J.S. Kisekka, V. Kongo, B.M. Mati, D.N. Moriasi, and S.E. Munishi. 2023. Data-Driven Decision Support for Improved Water Security in East Africa. FINAL REPORT. West Lafayette, IN: Long-term Assistance and Services for Research - Partners for University-Led Solutions Engine (LASER PULSE Consortium). https://bit.ly/eaws-finalreport

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Photo 3: Improper solid waste management continues to be a much-overlooked threat to the integrity of water resources and to water security in general. *Photo credit: Chrisogonous Peter, 2022.*

ACRONYMS

Acronym	Description
AQ_Rchrg	Aquifer Recharge
CMIP	Coupled Model Intercomparison Project
ET	Evapotranspiration
GW_Q	Groundwater Flow
LatQ	Lateral Flow
PERC	Percolation
REVAP	Revaporation
SurQ	Surface Runoff
SWAT	Soil and Water Assessment Tool
USAID	United States Agency for International Development
VFS	Vegetative Filter Strips
WYLD	Water Yield
YA	Young Adult

EXECUTIVE SUMMARY

Water Security is defined as the capacity to have enough water of sufficient quality and at the right time to support livelihoods, ecosystems, and economic activities. In East Africa, surface and ground water availability varies substantially with time and climate, and across subregions. Climate, land use, and land management changes are key factors affecting the integrity of water resources in the three countries, yet related data are generally insufficient, unavailable, or inaccessible for effective decision-making and management. The overall goal of the project was to provide water information, data access, and decision support to improve water resources (quantity, quality) management and, ultimately, water security in East Africa. Specifically, to: 1) Develop a broad dataset describing trends and current and future states of water resources in the study region; 2) Provide results, data, and base model parameters in such a way that these are easily discoverable, accessible, ready to use, and free; and, 3) Provide training to water resources managers, related personnel, and other stakeholders on the use and interpretation of the results, data, and other materials developed through this project.

In addition to developing a variety of datasets and data products, we conducted case studies in three key watersheds—Murchison Bay Watershed (Uganda); Simiyu River Watershed (Tanzania); and, Sasumua River Watershed (Kenya), reflecting a variety of climatic and landscape regions and allowing information to be differentiated by key threats to water security, primarily urbanization, climate change, land degradation. Based on the analysis, Sasumua River Watershed is projected to experience an increase in rainfall which would result in substantially higher flows into the Sasumua Reservoir. The most effective management approach to reducing mean annual sediment and nutrients in runoff will involve combining multiple practices, with the most effective single practice being filter strips. Simiyu River Watershed is projected to experience increased water flows and nonpoint source pollutants in response to changes in climate and land use, necessitating progressive and dedicated action on sustainable land use and conservation practices. Murchison Bay Watershed has been experiencing population increases over the past two decades which have led to dramatic land use changes, which are responsible for higher stream flows and the growing prevalence of floods. We have recommended management practices to mitigate these effects. Furthermore, we developed a variety of research translation products to help our stakeholders and other end users understand and use the data products, modeling results, and other outputs from this project. This project provided the water information, data, and training needed to improve water resources decision-making and management and, ultimately, water security in East Africa. We also built local capacity through training for water resources managers and related personnel, policy makers, and youth, allowing our methods and tools to be applicable in other locations beyond the pilot study locations and adaptable to the African continent and beyond.

Key Takeaways

1. There is the need for dedicated investment in data collection and curation by governments and the corresponding commitment to make the data freely available and accessible at least to researchers.

2. Overall key recommendations revolve around the need for sustainable environmental management within the watersheds, and improved access to data for decision-making if water security is to be achieved in the present and into the future.

3. Early career interventions targeting female YA in the water sector are needed to avert a leaky pipeline.

Introduction

Water Security refers to the capacity to have enough water of sufficient quality and at the right time to support livelihoods, ecosystems, and economic activities (Grey and Sadoff, 2007). Surface and ground water availability in East Africa varies substantially with time and climate, and across subregions. Climate, land use, and land management changes are key factors affecting the integrity of water resources in the three countries, yet related data are generally insufficient, unavailable, or inaccessible for effective decision-making and management with respect to water resources. Using methods documented by Daly et al. (2007) and Viney and Bates (2004), for example, project personnel showed that daily precipitation data that were readily available and accessible for the region were consistent and unbiased. In general, however, available climate data were limited in spatial and temporal extent, and often not accessible. Reanalysis data (Saha et al., 2010) was found to provide a viable alternative to measured climate data, but needed correction especially for precipitation (Gitau et al., 2018; Garibay et al., 2021).

This project focused on three East African countries—Kenya, Tanzania, and Uganda—to provide water information and data access for water resources decision making and management and, ultimately, improve water security across the region. Water resources challenges are similar among the three countries even though localized climates may differ substantially. Case studies were conducted in three key watersheds, one in each country. These watersheds represent a variety of: landscapes from mountainous to coastal; and, threats to water security including urbanization, climate change, and land degradation. Project PIs and partners had already been working in these watersheds and in the East Africa region in general, thus this work leveraged not only previous research data, but a well-connected and highly functioning research team.

In this project, all water information and processed data were packaged and deployed so as to be Findable, Accessible, Interoperable, and Reusable (FAIR) in accordance with open data FAIR Guiding Principles (Wilkinson et al, 2016). Results reflect the variety of climatic and landscape regions and information can be differentiated by key threats (urbanization, climate change, land degradation).

Case Studies

Table 1 provides a summary of key characteristics of the study watersheds. The similarities and differences across watersheds, along with the existence of prior work by PIs, made them ideal study sites for this project. Details of each watershed are provided in the pages that follow.

Table 1: Characteristics of the Study Watersheds

Watershed	Characteristics	Current Threats
Sasumua River Watershed, Kenya (Mwangi et al., 2015)	• Area: 136 km^2 • Average annual rainfall: 1,000–1,600 mm. • Land use: primarily agricultural and forested • Provides 20% of the water supply for the City of Nairobi.	• Erosion and flooding in the western and central parts • Land degradation • Associated water quality impacts

Watershed	Characteristics	Current Threats
	• Western and central parts characterized by poorly drained soils	
Simiyu River Watershed, Tanzania (Mulungu and Munishi, 2007; Rwetabula et al., 2007)	• Area: 10,659 km^2 • Average annual rainfall: 700 mm–1,000 mm • Simiyu River is ephemeral • Waters discharged into Lake Victoria • Primary land uses: Grassland, woodland, cultivated land • Water uses: agriculture, fishing and livestock production.	• Water fluxes due to land use/land cover change • Pollutants in water courses • High rates of erosion
Murchison Bay Watershed, Uganda (Kiggundu et al., 2018)	• Size: 40.9 km^2 • Average annual rainfall: 1,290 mm • Supports a variety of human activities • Core changes: urban expansion (29%); decreases in agricultural areas (18%), forests (6%), and wetlands (7%)	• Anthropogenic perturbations particularly land use/land cover change • Associated water quantity and quality impacts

Sasumua River Watershed, Kenya

The 136 km^2 Sasumua River Watershed is located in Nyandarua County and lies within the headwaters of the Tana River Basin. Elevations in the watershed range from 2,250 to 3,880 meters above sea level on the southwestern portion of the Aberdares Mountain Range, with annual rainfall ranging between 1,000 and 1,600 mm, depending on altitude. Situated within the watershed, the Sasumua Reservoir has a storage capacity of 15.9 million m^3 and contributes approximately 12-20% of Nairobi's water supply. An aqueduct connects Chania River to Sasumua River 5 km upstream of the dam, and water is diverted from Kiburu River to the reservoir. Primary land use in the watershed transitions from agriculture (intensive small-scale cultivation with typically less than 1ha parcels) to forest (Aberdare Forest) as elevation increases.

Agricultural activities have encroached on natural ecosystems above the dam (Figure 1). Land fragmentation with intensive agriculture and use of inputs pose a threat to water quality in the reservoir. The Jabini urban center which sprang up above the Sasumua Dam after it was built is growing rapidly, also posing pollution threats to water resources. Water from the reservoir benefits the city of Nairobi amid shortages for watershed residents. Furthermore, the impacts of climate change and associated threats to watershed water resources have not been adequately quantified.

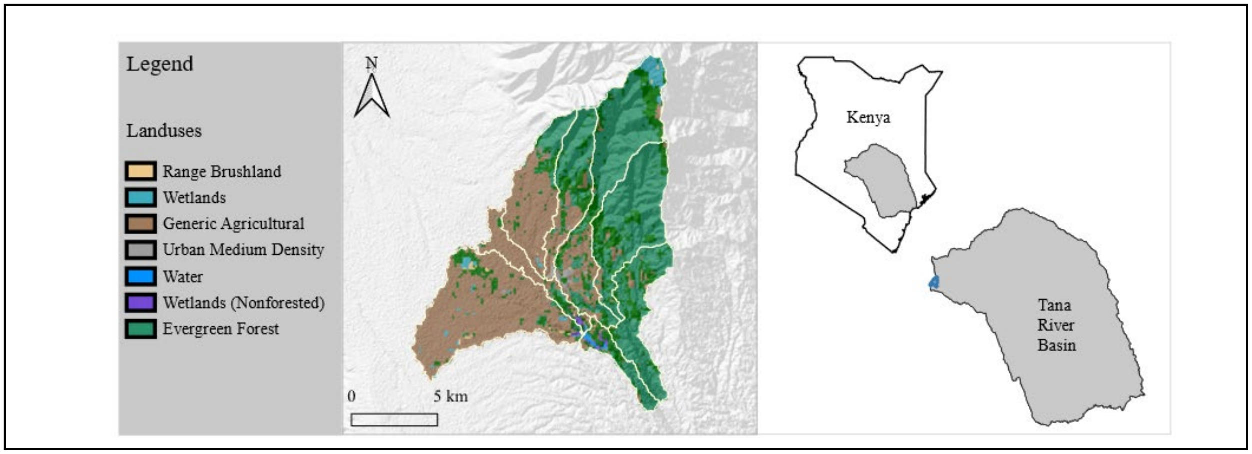

Figure 1: Sasumua River Watershed location and land use.

Simiyu River Watershed, Tanzania

The 10,659 km^2 Simiyu River Watershed is located between Simiyu and Mwanza regions in Tanzania (33.15º to 34.90º E and 2.15 º to 3.20 º S) and is part of the larger Lake Victoria basin, with the Simiyu River draining into Lake Victoria. The catchment is important with respect to food security in the country, as it contributes substantially to agriculture, fishing and livestock. The annual rainfall of the catchment ranges between 700 mm to 1000 mm with an average temperature ranging between 22.5 ºC and 23 °C. About 60% of the catchment is covered with sandy loam soil. Historically, the Simiyu River watershed had extensive vegetation with rich tree canopies, which moderated the hydrological cycle within the watershed providing water in abundance for the variety of uses. Extensive land use changes (Figure 2), driven by population growth, have constituted progressive increase in cultivated and built up areas with corresponding disappearance of forest and natural vegetative cover, posing a threat to water security.

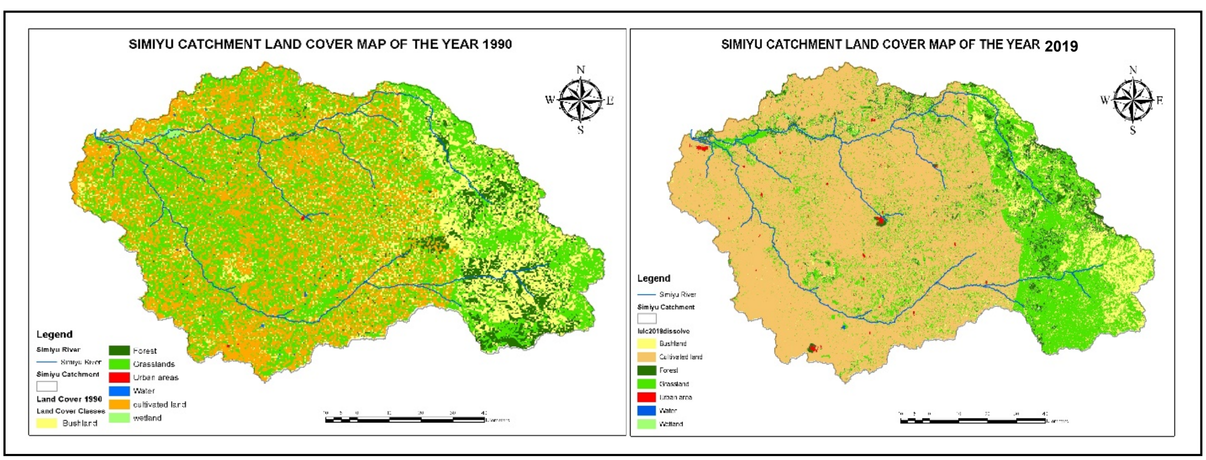

Figure 2: Simiyu River Watershed map showing land use changes occurring between 1990-2019.

The Simiyu river yields a high amount of sediments, nitrogen and phosphorus all of which end up in Lake Victoria (Mwanuzi, 2006 citing Machiwa, 2002; Kimwaga et al., 2011). Rainfall fluctuates highly between seasons and from one year to the other, which negatively impacts on watershed communities who depend predominantly on rain-fed agriculture and livestock production. Data on the impacts of land use and climate changes on watershed hydrology are largely insufficient, resulting in a poor understanding of watershed responses which, in turn, impacts negatively on water resources decision making and management.

Murchison Bay Watershed, Uganda

Draining into Lake Victoria, the Murchison Bay Watershed in Uganda covers and area of 40.9 m^2. Average rainfall in the watershed is 1,290 mm. The watershed supports a variety of human activities. Key anthropogenic perturbations include land use/land cover change (Figure 3) and degradation of natural resources (Anaba et al, 2017), with a primary concern being rapid urbanization largely related to the Greater Kampala Metropolitan Area. Impermeable surfaces—including roads, buildings, and courtyards—have increased on hill slopes resulting in increased runoff. Wetlands and other natural drainage systems in low-lying areas have been taken up by a variety of land uses including farmland, residentials, and industry. Current and future impacts of these changes on both water quality and quantities have not been studied extensively and are poorly understood.

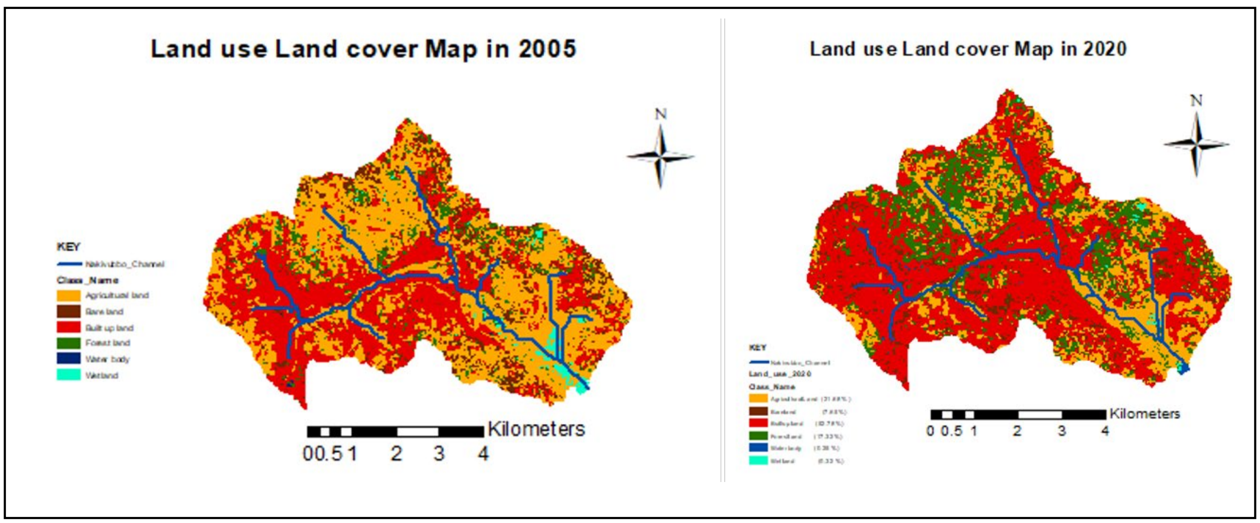

Figure 3: Murchison Bay Watershed map showing land use changes occurring between 2005-2020.

Project Design, Partnerships, and Approaches

The overall goal of this project was to provide water information, data access, and decision support to local actors who can then improve water resources (both quantity and quality) management, policy and, ultimately, water security in East Africa.

We postulated that *availability and access to science-based insights on current and potential future states of water resources in the study region will improve the way water resources are managed and lead to increased water security in the region*.

Goals/Objectives

Specific goals were to:

1. Develop a broad dataset describing trends and current and future states of water resources (quantity and quality) in the study region
2. Provide results, data, and base model parameters in such a way that these are easily discoverable, accessible, ready to use, and free; and,
3. Provide training to water managers, policy-makers and other water resources personnel on the use and interpretation of the results, data, and other materials developed through this project.

Project partnerships

The project team comprised two sub-teams—the Research Team and Translation Team. The Research Team comprised researchers from Purdue University and USDA-Agricultural Research Service in the U.S.A., Makerere University in Uganda, and University of Dar es Salaam in Tanzania. Translation partners comprised: Stichting Aidenvironment (RAIN, Uganda), Global Water Partnership Tanzania (GWP-TZ), and Resource Plan (Kenya). RAIN implements water-related projects and programs in Uganda. The GWP-TZ is concerned with sustainable development and management of land and water resources. Resource Plan Ltd is a privately-owned company that deals with water management in Kenya.

Both sub-teams worked closely together from the on-set in a co-design process, including research planning and the design, development, and packaging of project products, to ensure that products produced through this project were directly relevant and readily applicable in a local context. Translation partners were also instrumental in reaching target audiences for training, and reviewing training materials to ensure that these are understandable by knowledgeable, non-technical audiences within a local context.

Project approaches

Research

We used a combination of existing climate data, rainfall data that we have recently developed, and a modeling approach to conduct our analysis. We updated existing datasets including streamflow, water quality, and climate data with currently available information. We also obtained downscaled future (CMIP 6, Riahi, K., et al., 2016) climate datasets from online portals for use with the modeling studies. In addition, we acquired other water resources data such as groundwater and water usage data as available. We used any additional climate data to improve and/or develop additional climate series from reanalysis data as had been done previously by project PIs. We used the Soil and Water Assessment Tool (SWAT, Arnold et al., 1998) to evaluate water budgets in each study basin and determine the status of water resources for past (as reference point), current, and future (prediction/forecasting) timelines. Scenarios evaluated and grouping of future datasets varied among watersheds and was largely dependent on current threats to water security in the specific area. In addition to water budgets, we obtained model outputs of sediment, nutrients including nitrogen and phosphorus, and other water quality components. Details of the modeling efforts, outputs, and recommendations are provided in this Modeling Snapshots document.

Additionally, we conducted more in-depth analysis on current and future climate data to identify precipitation and temperature patterns and extreme characteristics. The data were analyzed to establish patterns and changes in daily, monthly, and seasonal rainfall. Associated extremes quantified included: annual 1-day maximum precipitation; number of wet days in a year; number of wet days in a season; periods of and contributions from heavy and very heavy rainfall (95th and 99th percentile rainfall, respectively), as well as patterns and changes in mean maximum and mean minimum temperatures, as these were most relevant to the study watersheds. These characteristics have previously been quantified by Mehan et al. (2017) and Gitau (2018) and are consistent with extreme indices described in the literature (e.g. Schär et al., 2016; Zhang et al., 2011; Klein Tank et al., 2009; and, Groisman et al., 2005).

Stakeholder Engagement

Throughout the project, project PIs and Translation Partners met with different stakeholders to discuss the project and present project results. In May 2021, we held our inaugural Stakeholder Meeting (in Nairobi, all virtual via the Zoom due primarily to the travel challenges posed by COVID-19). The virtual meeting presented an opportunity to engage as many participants in Kenya, Tanzania, and Uganda as possible, with a record 72 participants (double the targeted number) attending the meeting. This meeting comprised a variety of presentations—covering topics including water security, data and data-driven approaches for water resources, and the value additions of stakeholder engagement—and open discussion sessions for Questions and Answers and further exchange.

Training Workshop

We developed a variety of training materials that include: a training manual; a trainer's (facilitator's) guide; presentations; an exercise workbook with worksheets; and, participant consent and photo release forms, which we have packaged together in one document and made accessible in both electronic and hard copy formats as needed. The incorporated trainer's guide provides details on the planning and delivery of the training sessions, and procedures for collection data on participants and their perspectives (detailed further under Gender Considerations). The training was held in September 2022 (Dar es Salaam, Tanzania), in hybrid mode, and included rapid response questions with individual responses collected on notecards (in-person participants) and via Zoom chat (virtual participants).

In addition, we conducted rapid evaluations via an online/app audience engagement system (PollEverywhere) to evaluate learning, and/or obtain participant perspectives and suggestions for future engagement. This allowed us to better engage all participants including those who might have been reluctant to speak up in a group or those, for example women and youth, who might have been deterred by societal norms (Muñoz Boudet et al., 2013). All training materials will be informed by and co-designed with translation partners to ensure that the materials were understandable by knowledgeable, non-technical audiences within a local context.

Gender Considerations and Audience Recruitment

We worked with our translation partners to actively recruit women and youth (young adults ages 18-34, both female and male) to participate in stakeholder meetings and training sessions. Our target was for a 50-50% participation of men-women and at least a 25% participation of youth. For both the Stakeholder Meeting and the Training Workshop, we initiated campaigns through our translation partners to reach our intended audiences from entities such as: Ministry of Water or equivalent in all three countries; Ministry of Environment and Natural Resources or equivalent in all three countries; Lake Victoria Basin Commission; hydro-electric power generation companies in all three countries; water supply and sewerage entities as available in all three countries; and, Non-Governmental Organizations. Campaigns comprised announcements strategically targeted and spaced to allow prospective attendees to plan for the activity ("save-the-date" announcement followed by flyers and more detailed information on agenda and topics) and targeted invitation letters to ensure specific entities of interest were represented.

Given societal norms regarding professional roles for women, we reached more broadly and at different levels within organizations as needed to ensure that we engaged women stakeholders and training participants. In addition, we targeted youth (both young men and young women) by recruiting participants from local universities in departments such as biosystems engineering, civil/water resources engineering, environmental science, geography, or related areas. Societal norms and perceptions may limit women's mobility and the time frame (e.g. daytime only vs evening activity) in which they can be engaged (Lovell and le Masson, 2014; Muñoz Boudet et al., 2013). Thus, we scheduled the Stakeholder Meeting and Training Workshop to start and end during hours considered acceptable within a local context and ensured that training materials were accessible outside of the formal training session. In addition, we packaged our training materials to enable self-paced learning and made these available in both digital and print media to ensure access by those with limited mobility.

During the Stakeholder Meeting and Training Workshop, we kept track of input coming from men separately from that coming from women to the extent that it was possible. Data from these events were compiled progressively after each event and used to evaluate whether we are meeting our targets for engagement or if gender-related interventions would be needed. For both events, we used an online registration application—Qualtrics, provide through Purdue University—to pre-register participants and request information on sex and age, to help us keep track of participants and adjust recruiting strategies accordingly. Data collected were analyzed to provide a sex-differentiated picture of participants. We also conducted evaluations during the training to collect sex disaggregated information on participant perspectives on the training and obtain any suggestions they might have for future training.

Study Results and Associated Products

We packaged our data and results in three different formats based on anticipated users and uses, and following FAIR data principles: (1) Processed data and results were packaged to provide actionable information and enable their use by water resources managers and other water professionals in water resources decision-making and management; (2) Snapshot visualizations of aggregated results in a variety of forms—including graphs, charts, maps, and color bars—with accompanying text narratives, targeted at the individual, including researchers, practitioners, water resources managers, and youth, and containing information on how to access other project products; and, (3) Raw data (as available and shareable), processed data, and base model parameters packaged to enable their use in research and targeted at personnel in higher education and/or research institutions and consultants.

In addition to the data and results, we provided complementary products including: online visualizations of detailed data and results using graphs, charts, or maps; a Quick Reference Guide; a Training Manual; Peer Reviewed publications; and Policy Briefs for each country stemming from the research results. All products developed through this project are packaged for easy access and download and interoperability with different models and tools (e.g. as *.csv, *.txt, *.pdf) and, where feasible, published with a DOI to provide an easy and perpetual reference. All project products were co-designed by the Research and Translation teams and were reviewed by translation partners, with adjustments and improvements made to the packages as needed before deployment. Detailed citations of our products are provided in the Appendix.

Water and climate (current and future) data for the study areas.

We acquired, collected, and deployed available water and climate data for the study watersheds. Base data for the study areas, in combination with rainfall and temperature datasets developed from reanalysis data by the research team, were all leveraged to provide higher impact in the study. We also updated existing datasets including streamflow, water quality, precipitation, and temperature data with currently available information. In addition, we acquired other water resources data including reservoir capacity and levels as available. In this effort, we worked with our translation partners as needed to acquire water resources data through their contacts with government agencies and other entities that maintain datasets.

We packaged the data (as raw data where permitted or aggregated otherwise) using FAIR data principles and published this through the Purdue University Research Repository (Figure 4) with appropriate embargoes and releases as described in our data management plan. Interested parties will be able to access the project data on the Purdue University Research Repository (PURR) via USAID's Development Data Library (DDL), as well. Most of the data is deployed for public use, with the exception of Sasumua River Watershed, which is designated as a security area and therefore, we aggregated available data to at least an annual level and/or extracted statistics at the annual level, which we then deployed. Also, for Sasumua River Watershed daily precipitation and temperature series were developed from reanalysis data as available data were only available on a monthly basis (and could not be shared).

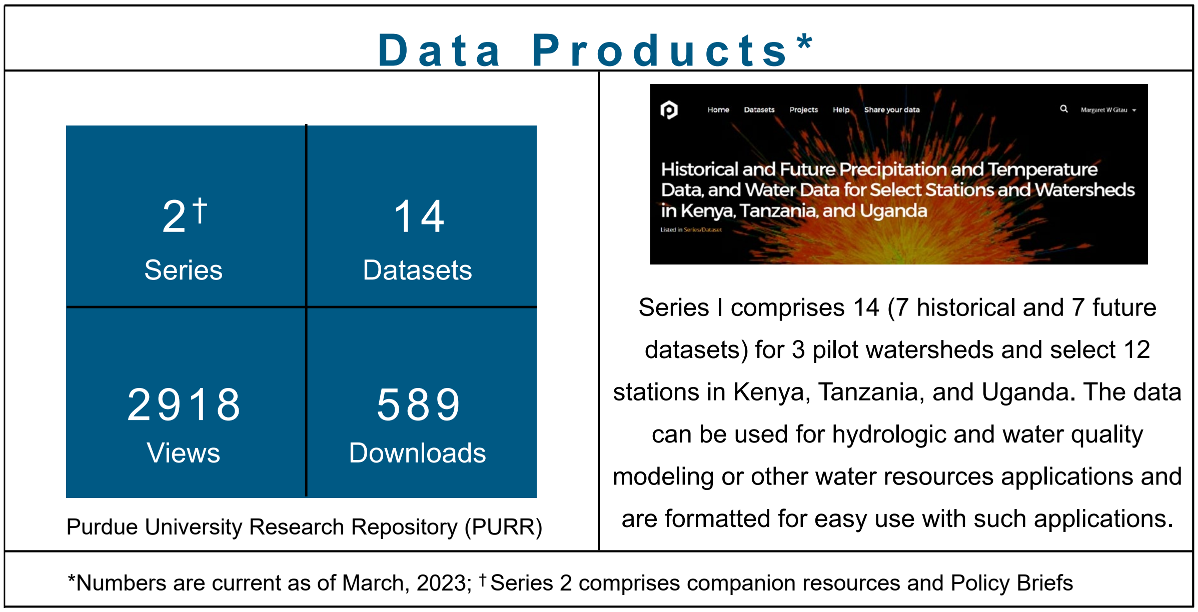

Figure 4: Summary of data products published through the Purdue University Research Repository. Detailed citations for each product along with companion resources are provided in the Appendix.

Raw and processed data were packaged for easy download and interoperability with different models and tools (i.e.: as csv; standardized using ACDD-1.3 and CF Standard conventions; dates provided using ISO format, etc.). Detailed metadata were provided with the datasets, in both machine- and human-readable formats. These datasets are targeted at personnel in higher education and/or research institutions and consultants for use in conducting water resources research and assessments.

Water budgets and model outputs for current and future timelines

The SWAT model was set up and calibrated and validated for: Sasumua River Watershed, Kenya; Simiyu River Watershed, Tanzania; and, Murchison Bay Watershed, Uganda which are diverse in their characteristics and focal issues. Model results were used to investigate the effects of changes in land use, climate, and mitigation practices as relevant to each case study (Figure 5). Details of the modeling work are available here.

In September 2021, we travelled to Kenya and visited the project site and met with GIS specialists at Kenya's Water Resources Authority (WRA) to conduct a ground truthing, get updated perspectives on prevailing management practices and field operations in the watershed, and verify our data points. During the visit, we had the opportunity to interact with the leadership of the watershed's Water Resources Users Association (WRUA), watershed managers (Upper Tana/Nyandarua County), and water resources managers (Nairobi Water Company) which allowed us to obtain a variety of perspectives on water resources concerns in the watershed, and gain insights that helped improve our modeling evaluations and better tailor our work to the needs of the different stakeholders. We also visited with technical personnel at WRA to discuss water resources management scenarios that would be of interest to them. We incorporated these scenarios into our modeling, such that our results are directly relevant to and actionable for them.

<u>Based on the modeling analysis:</u>

Sasumua River Watershed: Water flows are expected to more than double for three of four future scenarios compared to the baseline period (2011-2020). The single best management practice for reducing watershed sediment losses was found to be filter strips while a combination of riparian buffers, filter strips, terracing, field diversions, and water harvesting ponds (all suitable and practical management practices) would provide the best outcome.

Simiyu River Watershed: In comparison to the baseline period (1971-1999), precipitation has increased by 62% and is expected to more than double in the future (2030-2060). In response, increases are expected in overland flow and total water yield in all future climate scenarios, potentially leading to increased flooding. Sediment losses are expected to increase by more than 7% in response to land use changes occurring within the watershed.

Murchison Bay Watershed: Increases in stream flow, surface runoff, and some nutrients have occurred due to changing land use, which is attributable to increasing population growth within the watershed. These increases are projected to continue through 2040. Vegetative filter strips (2 m and 5 m) and retention ponds (20 m^3) could reduce sediment yield by 42%-70% and surface run off by 60%, respectively.

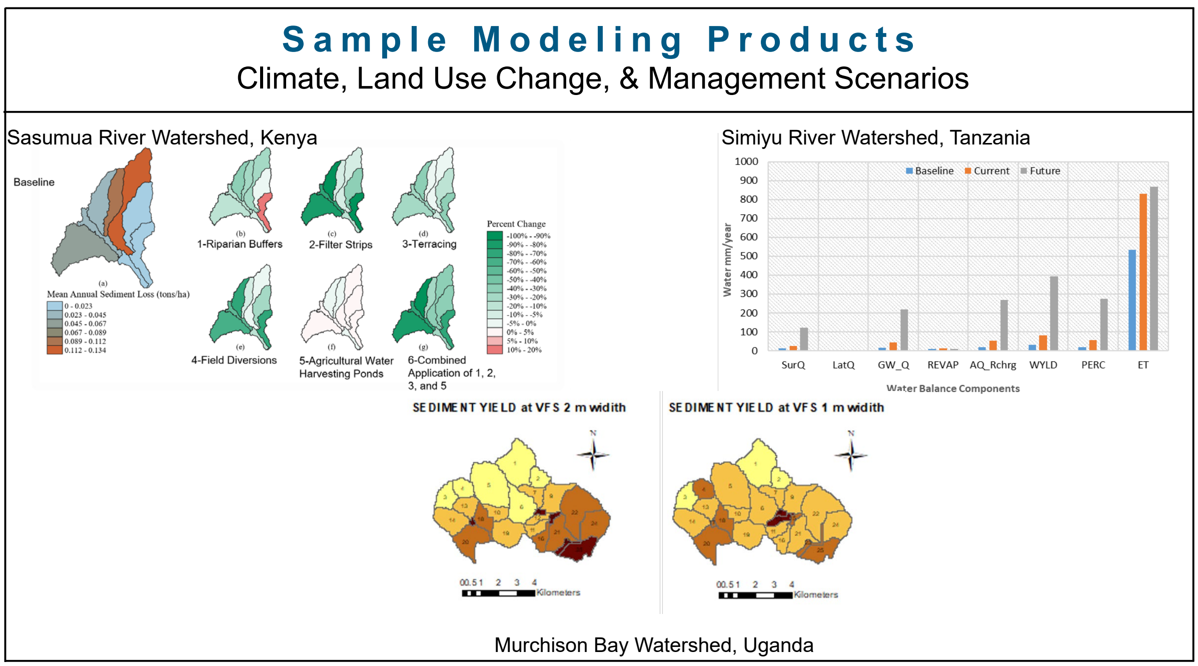

Figure 5: Sample modeling products developed based on guidance from Translation Partners, watershed-specific needs, and inputs from the various stakeholders.

Patterns and changes in daily, monthly, and seasonal rainfall and associated extreme characteristics

We analyzed climate data in-depth to identify shocks, looking at both historical and future data. From these data, we established patterns and changes in daily, monthly, and seasonal rainfall and identified extremes including: annual 1-day maximum precipitation; number of wet days in a year; number of wet days in a season; periods of and contributions from heavy and very heavy rainfall (95th and 99th percentile rainfall, respectively), as well as patterns and changes in mean maximum and mean minimum temperatures, as these were most relevant to the study watersheds. We packaged these data and results into an interactive dashboard (Figure 6), which we deployed with our other data products.

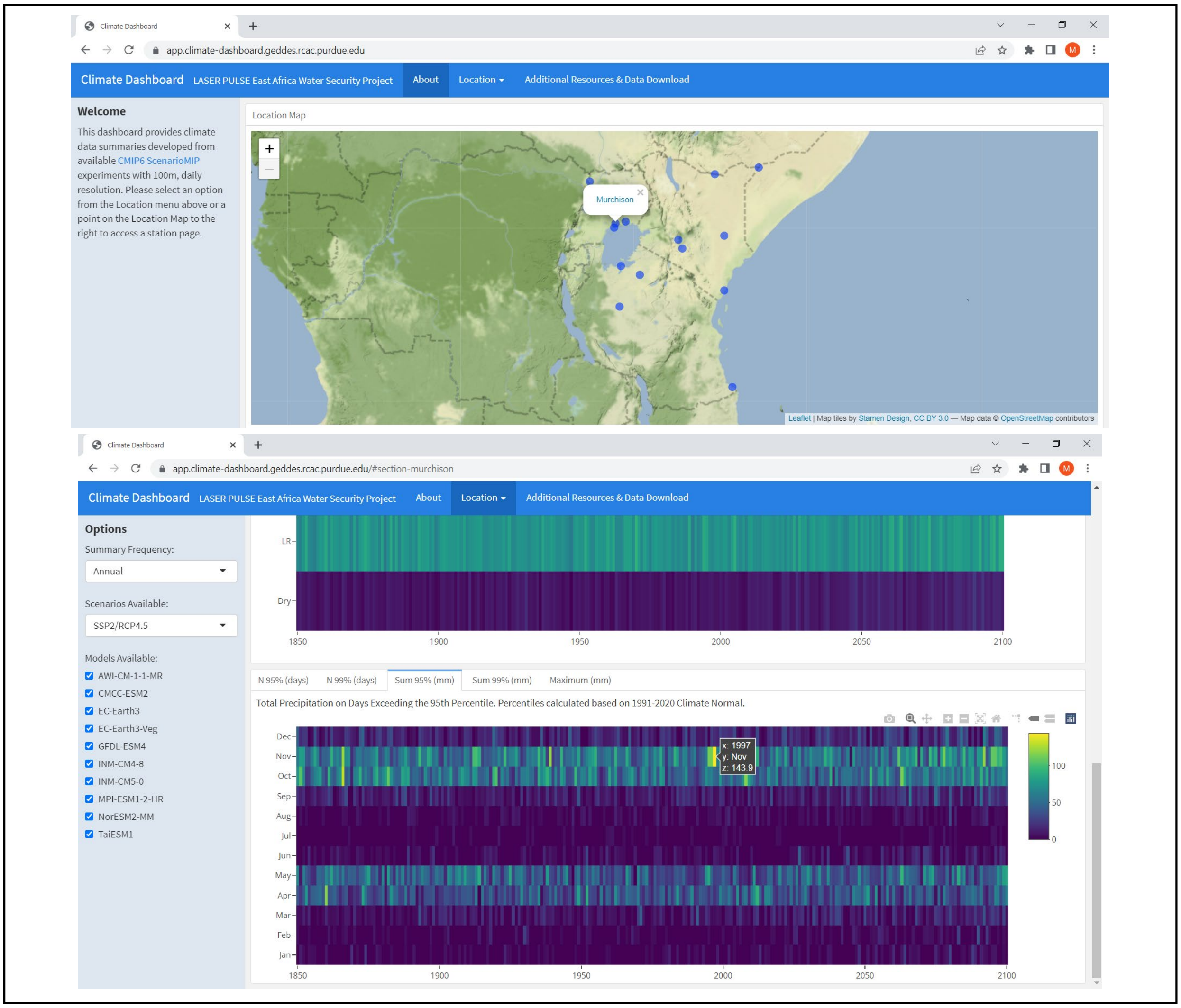

Figure 6: Screenshot of Climate Dashboard showing stations, access to additional resources and data downloads, pull-down menus, and sample visualization. Station names show up on click and clicking on the station name takes the user to detailed data for the respective station.

Companion products

A 7-page Quick Reference Guide was developed to go with the various data products and model results. This Guide provides a summary of the data and modeling products that have resulted from the project, their purpose, where to find them, and how they can be used. The Guide comprises visual content with text kept to a minimum. The actual content was informed by discussions with translation partners to ensure it meets user needs. The target audience for the Guide is higher-level administration and management-level users who might not have the time or need to go through the training or training manual but, nonetheless, need to be informed about our results and associated products. Companion documentation includes a Modeling Snapshots document, Training Manual, and Workshop and Stakeholder Meeting reports as detailed in the Appendix.

In addition, we have produced: two peer reviewed publications from this work, with a third one in the making; Model Parameters for each watershed provided in csv format; Data Visualizations; a variety of Presentations; Websites; and, Policy Briefs, one for each country. Detailed citations of these products along with links to access are available here.

Stakeholder Engagement and Capacity Building

During the course of the project, we held one formal Stakeholder Meeting and a Training Workshop. In addition, project PIs and Translation Partners met with different stakeholders—such as the Lake Victoria Basin Commission, Tanzania Director of Water and Direct Reports, Kenya Water Resources Authority, Sasumua Water Resources Users Association, USDA-Agricultural Research Service, and USAID—at different points during the project period to discuss the project and present project results.

Stakeholder Engagement

The need to involve all interested parties early during the project, rather than informing them of the study results at the end of the project, was well noted. A time-lapse (typically 2-5 years or more) is often experienced between the release of actionable results and meaningful change due to the long time needed for people to adapt to new ways of doing things, considering cultural norms and perceptions. When communities are engaged early through their local leadership, acceptance of research results becomes a gradual process leading to mutual benefits for all. With adequate funding, existing study sites can be purposed/re-purposed to serve as demonstration sites for technologies and intervention recommended by project personnel. This also makes it easy to influence policy given the practical demonstration of recommended practices.

Capacity Building

Capacity building and training efforts are much needed within the study region. Training needs to be tailored to provide the necessary knowledge on aspects including: software use, modeling skills, and programming; interpreting model and research outputs; research translation; research communication—particularly where results might be disruptive; data benefits and beneficiaries; and data processing and curation, among others. Alongside these training needs, is the need to target a variety of audiences including researchers, practitioners, policy makers, communities, and journalists and maintain continuous engagement through workshops. Depending on the content and context, these target audiences can be engaged as separate or combined audiences. In our recently completed workshop, the benefit of combining audiences was evident; if nothing else, each party was exposed to the perspectives, priorities, and work circumstances of other parties—conditions which are critical to moving towards a common understanding and effective solutions. More than that, combining audiences contributed to the richness and depth of discussion and opened opportunities for collaborations and engagements that will be mutually beneficial.

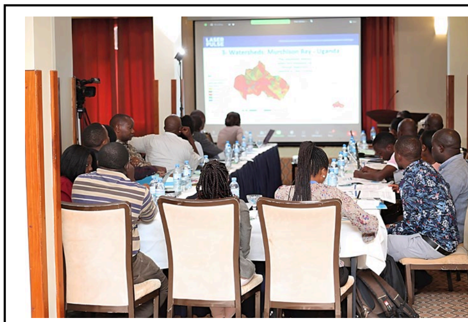

Photo 1: Training workshops and other capacity building activities will be key.
Photo credit: Frank Anderson, 2022

Gender Considerations

Stakeholder Meeting: The aforementioned Stakeholder Meeting was well attended with 72 attendees recorded on the Zoom platform, 47 of whom had registered formally for the meeting. As it was not always possible to discern sex and age from the Zoom-generated list of participants, statistics reflect the 47 registered. Of the registered participants, 32% were female and 68% were male. Forty five percent were young adults (students and early career professionals in the water area ages 18-34), largely exceeding our target of 25%. Representation of females was better among the young adult participants (38%) than that among seasoned professionals (27%). Female/Male representation varied by country: Kenya (47%/53%); Tanzania (10%/90%); and, Uganda (32%/68%). Representation by young adults (YA) also varied by country: Kenya (60%); Tanzania (20%); and, Uganda (45%). Several sectors were represented including academia, NGOs, government, and the private sector. Distribution of females and males (Figure 7) did not differ substantially across sectors; for example: 33% of female participants came from government agencies compared with 34% of male participants, and similarly for other sectors. A majority of the young adults (YA) came from academia (38%) and NGOs (29%), with substantial representation from government (24%), while a majority of adults age 35 years and over came from government (42%), with substantial representation from NGOs (23%).

Training Workshop: Participant recruitment comprised a targeted campaign with attention to meeting attendance goals of 30-35 participants, 50/50 distribution between men and women, and a minimum of 25% YA. A total of 57 persons either registered online and/or provided their information on-site (registrants) with countries represented including Tanzania, Uganda, Kenya, Germany, and Rwanda. Of these, at least 35 attended the workshop, based on information recorded on site and attendance information from the Zoom participant record. As it was not always possible to keep track of online attendees and to discern sex and age from the attendance listing of online participants, the statistics provided in Figure 7 reflect registered participants.

Figure 7: Registrant demographics for Training Workshop by: (left) Male/Female in each country; (center) young adults (YA) and registrants age 35+ in each country; and, (right) Sector. KE: Kenya; TZ: Tanzania; UG: Uganda; E: external to the project countries.

EARLY CAREER INTERVENTIONS TARGETING FEMALE YOUNG ADULTS IN THE WATER SECTOR ARE NEEDED TO AVERT A LEAKY PIPELINE.

Of the registrants, 42% were female and 58% were male, which was fairly close to our 50/50 goal. Female/Male representation varied by country: Kenya (39%/61%); Tanzania (33%/67%); Uganda (50%/50%), the only country to achieve the target; and, External (67%/33%).

Fifty five percent were YA, largely exceeding our target of 25%. Representation of females was better among YA registrants (45%) than that among seasoned professionals (36%), which was consistent with observations from the Stakeholder Meeting. Representation by YA also varied by country: Kenya (39%); Tanzania (59%); and, Uganda (67%). Several sectors were represented with the largest representation being from academia (56%), and the lowest from the private sector (9%). Distribution of females and males was proportional among registrants from academia (50%/50%) with female underrepresentation being observed in registrants from NGOs (33%) and government (18%). A majority of the YA came from academia (52%) and NGOs (23%), consistent with the picture from the Stakeholder Meeting, while a majority of participants age 35 years and over came from academia (60%) and government (32%).

Participation: During the Training Workshop, rapid polls via the Poll Everywhere audience-engagement app were conducted at the end of each module to gage what participants had learned and if there were anything more they would have liked to have known. The polls were not anonymous in order to allow us to discern sex and age information; however, some participants did not use their real names or full names. Where it was possible to do so, identifying information was linked back to participant registration information to discern information on sex and age.

A total of 30 comments were obtained through rapid polls, of which 23 could be characterized based on sex and 21 could be characterized based on age. Multiple responses from the same participant were considered as separate inputs, thus numbers reflect responses rather than respondents. Based on the information provided, substantially fewer comments were obtained from female participants than from male participants (13% vs 87%, respectively). It was, however, worthwhile noting that the number of comments obtained from YA were more or less the same as those obtained from participants age 35+, and was in fact slightly higher (52%). Between the two age groups, there was more interest in Modelling among YA, while participants age 35+ were more interested in Research Translation than were YA, based on number of comments obtained from each group. Interest in Data Policy was about equal.

Assessment: While we made substantial progress with respect to gender integration, the 50/50 target for female/male participation remained elusive for the most part. That said, it was encouraging to note that this target was close to being realized among the younger registrants (YA). The key issue that now presents itself is the need to keep this group of women continuously engaged to ensure their retention within the sector, even as they move into the mid- and late-stages of their careers. ***Early career interventions targeting female YA in the water sector are needed to avert a leaky pipeline—an unfortunately common phenomenon particularly in STEM fields.***

Key Takeaways

Data access is a still a challenge in developing countries. In some cases, government agencies lack the resources to collect data. In cases where data is collected it is generally inadequate and/or is termed "a security tool for the governments", which prevents it from being shared. Some data might be accessible at a fee, but the bureaucracies involved present enormous frustrations to researchers and practitioners looking to access and use the data.

During our discussions at the Training Workshop, it became clear that there was a conflict between user and custodian perspectives on making data freely available and accessible. While researchers and practitioners expressed their frustrations at the lack of access, data custodians maintained that the investment in data collection, processing, and management made it difficult for them to give it for free due to the need to recover their investment. The argument was made that the true value of the data lay in its use for development and that restricting its use, ironically, amounted to a loss in the investment. Participants concurred that the issue could be resolved through dedicated investment in data collection and curation by governments, and the corresponding commitment to make the data freely available and accessible at least to researchers. The potential for misuse of data in transboundary conflict was acknowledged by all parties, and the registration and screening of data requesters was proposed as a solution.

Sasumua River Watershed

Proximity of farmlands and emerging urban centers to water sources in the Sasumua River Watershed threatens water quality and increases the cost of drinking water purification. Increased future rainfall will result in substantially higher flows into the Sasumua Reservoir, potentially doubling the modern value within 70 years. The watershed management intervention found to be most successful at reducing runoff and pollutant losses was a combination of several concurrent practices, while grass filter strips was the most effective among single practices. Recommended actions include: **upscaling** grass filter strips/contour grass buffer strips as practices that could be implemented singly; and, **investing in data collection and curation** and committing to **make the data freely available** for research and decision-making.

Simiyu River Watershed

Changes in land use as a result of increased anthropogenic activities in a changing climate, have jeopardized the integrity of water resources in the Simiyu River Watershed. Climate projections for the watershed indicate an increase in total annual precipitation and temperatures. Future flows and sediment loads in the Simiyu River will increase, especially during the wet months, with ongoing uncontrolled landcover and land use changes having a large influence in partitioning the hydrological cycle in the watershed. Recommended actions include: **creating progressive and dedicated awareness** on sustainable land use and conservation practices along with **deliberate interventions on policy guidelines** and **strategic investments** in catchment restoration.

Murchison Bay Watershed

The Murchison Bay Watershed has experienced a dramatic increase in built-up land alongside decreases in bare land, agricultural land, and wetland cover. Surface runoff and sediment loading have increased, while groundwater replenishment has decreased. These changes result in destructive flooding and flash-floods, posing severe socio-economic challenges to businesses and residents. Recommended actions include: **implementing** integrated flood management that incorporates surface runoff and sediment reduction into land use plans, and aims to restore natural drainage systems; and, **investing in research and data acquisition** and commit to **make the data freely available**, to support evidence-based planning.

Overall

Overall key recommendations revolved around the need for sustainable environmental management within the watersheds, and improved access to data for decision-making if water security is to be achieved in the present and into the future. Recommended actions include:

- **Reducing** runoff flows, and sediment and nutrient loads using conservation practices such as grass filter strips among others;
- **Defining buffer zones** around key water courses and water bodies and enforcing against encroachment;
- **Controlling excess roof and surface runoff** water from **urban areas**;
- **Sensitizing residents** and agencies concerned on the need to protect water resources including **proper solid waste management**; and,
- **Updating water and data policies** to improve curation and access of data among relevant agencies and researchers to **ensure that data is accessible** for informing water resources management decisions.

Photo 2: Improper solid waste management continues to be a much-overlooked threat to the integrity of water resources and to water security in general.
Photo credit: Frank Anderson, 2022

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APPENDIX

Project Products Details and Citations

Following is a listing of products developed through this project along with complete citations and DOIs and/or links for access. Products are categorized in alphabetical order.

Data Series and Datasets

Gitau, M. W.; Garibay, V.; Kiggundu, N.; Kisekka, J.; Kongo, V.; Mati, B.; Moriasi, D.; Munishi, S. E. (2022). Historical and Future Precipitation and Temperature Data, and Water Data for Select Stations and Watersheds in Kenya, Tanzania, and Uganda. Purdue University Research Repository. doi:10.4231/DG18-V225. Data Series.

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Data Visualizations

Climate Scenario Exploration Dashboard: https://app.climate-dashboard.geddes.rcac.purdue.edu/

Simiyu River Watershed: https://www.gwptz.org/projects/simiyu_river_catchment/

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Garibay, V.M., and M.W. Gitau. 2022. East Africa Water Security Project: Quick Reference Guide. https://bit.ly/products-quickreference

Gitau, M.W., V. Garibay, N. kiggundu, D. Moriasi, J. Kisekka, S. Munishi. 2022. East Africa Water Security Project: Workshop Report. https://bit.ly/products-WorkshopReport

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Model Parameters in .csv Format

Gitau, M. W.; Moriasi, D.; Garibay, V.; Kiggundu, N.; Munishi, S. E. (2022). SWAT+ and SWAT Model Parameters for: Sasumua River Watershed, Kenya; Simiyu River Watershed, Tanzania; and, Murchison Bay Watershed, Uganda. Purdue University Research Repository. doi:10.4231/CKJ4-8354

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Garibay, V.M., M.W. Gitau, V. Kongo, J. Kisekka, and D. Moriasi. 2022. Comparative Evaluation of Water Resource Data Policy Inventories Towards the Improvement of East African Climate and Water Data Infrastructure. Water Resources Management. DOI: https://doi.org/10.1007/s11269-022-03231-z

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Mati, B.M. 2023. Data Driven Decision Support for Securing Kenya's Water Towers. Policy Brief. https://bit.ly/policybrief_Kenya

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https://www.gwptz.org/projects/simiyu_river_catchment/

https://web.ics.purdue.edu/~mgitau/projects-1.html

Best Management Practice Descriptions

Management Practice	Practice Description
Riparian Buffers	Indiscriminate buffer of rangeland around the stream network.
Filter Strips/Vegetated Filter Strips	Vegetated field border to slow down runoff and remove pollutants.
Terracing	Contoured terraces on 3-8% slopes with sod outlets implemented on agricultural land.
Field Diversions	Field diversion terraces at 40 m intervals on 3-8% slopes implemented on agricultural land.
Agricultural Water Harvesting Ponds	Addition of ponds on farms for irrigation modeled as equivalent subbasin pond.
Combined Application	Modifications for Scenarios 1, 2, 3, and 5 together.

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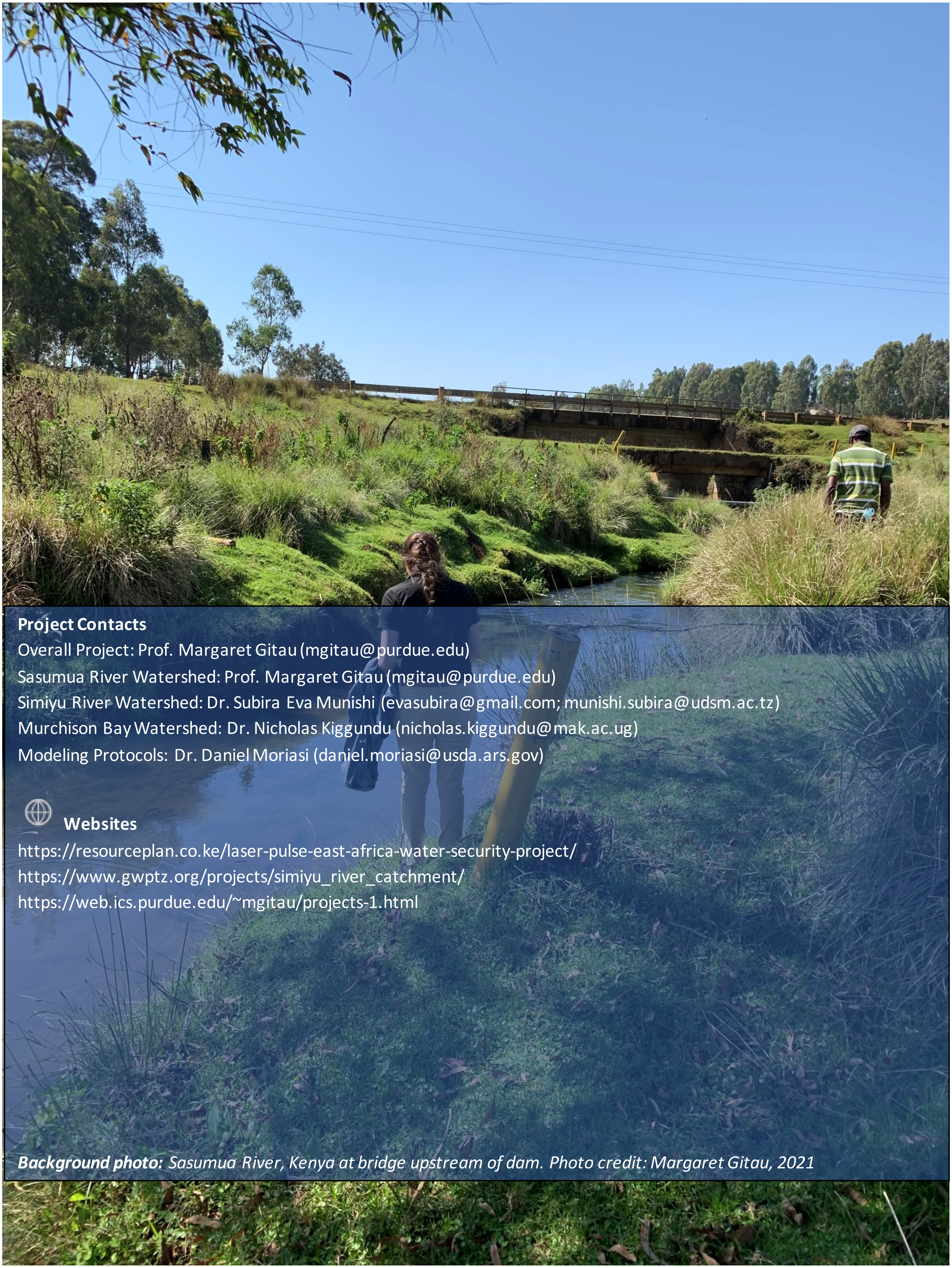

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Websites

https://resourceplan.co.ke/laser-pulse-east-africa-water-security-project/
https://www.gwptz.org/projects/simiyu_river_catchment/
https://web.ics.purdue.edu/~mgitau/projects-1.html

Background photo: *Sasumua River, Kenya at bridge upstream of dam. Photo credit: Margaret Gitau, 2021*