Laidlaw Research and Leadership in Action (Summer II: 2024)

Research Blog: Exploring Circular Bionutient Economy Pathways in Western Kenya.

Summary

My research internship this past summer utilized community-based translational research to address waste management, sanitation issues, and food insecurity. Our research insights could provide meaningful back-end insights such as effective ways to address climate change and how to reduce morbidity and mortality associated with poor sanitation.

Can CBE Transform Communities? - Manor House.

What is CBE?

The Circular Bionutrient Economy (CBE) is a subset of the Circular Economy (CE) that adopts the principles of designing out waste and pollution (Midega, 2022). It allows for the transformation of organic waste into valuable products such as organic fertilizers and animal feeds [1]. This helps in the recovery of nutrients by utilizing waste streams for reuse in Agriculture [2](Duncan & Gulbahar.)

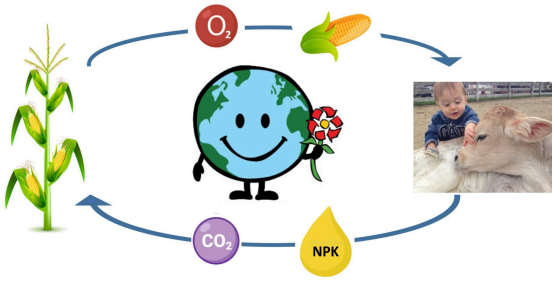


Illustration of circular nutrient elemental flow.

The right place at the right time with the right people.

[1] Charles A. O. Midega, "Opportunities for Circular Bionutrient Economy in Kenya: Sanitation and Waste Stream Characterization," *Urban Agriculture & Regional Food Systems* 7, no. 1 (2022): e20034, https://doi.org/10.1002/uar2.20034.

[2] Duncan Gromko and Gulbahar Abdurasulova, "Climate Change Mitigation and Food Loss and Waste Reduction: Exploring the Business Case" (Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), 2019), www.ccafs.cgiar.org.

Prof. Charles Midega, Director of Poverty and Health Integrated Solutions (PHIS) - a national research and development organization that aims to improve health by addressing proximal causes of poor health - and Prof. Rebecca Nelson, Professor, Department of Global Development at Cornell University, and I set out to visit Manor House Agricultural Center (MHAC) in Kitale, Western Kenya - a farmer training center for organic agriculture. The three of us have been working at the nexus of public health and agriculture and are part of the Circular Bionutrient Economy Network (CBEN) - an interdisciplinary network of CBE practitioners from East Africa and beyond [3](CBEN). CBEN aims to establish collective research, policy, and operational frameworks to support the regional value chains recovering nutrients from Organic Underutilized Resources (OURs) such as crop residues, market waste, livestock, and human excreta, and turn them into organic fertilizers, animal feeds, and soil amendments that farmers in East Africa can use to enhance soil health, livelihoods, and food security [4].

Prof. Midega, Prof. Nelson, and I.

To Collaborate.

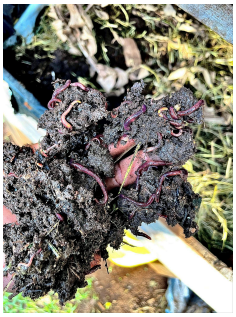
This was my first field visit of my summer internship and I was excited, and anxious about how I could channel my energy, skills, and ideas to best contribute to the CBE projects and opportunities that lay ahead. This visit aimed to seek an opportunity for us to collaborate further with the Farmer Research Network in the region, and the Sustainable Organic Farming and Development Institute (SOFDI) - an NGO based in the region that works to improve livelihoods through sustainable agriculture and rural development. Our discussion was about how we could partner to catalyze the adoption of resource-recovery in their agricultural practices to utilize various waste streams available in the region to address soil nutrient depletion. This was followed by logistical plans for execution such as sourcing for appropriate tools and designs for resource recovery and overcoming the anticipated barriers such as the stigma associated with animal and human excreta.

[3] "Circular Bionutrient Economy Network," CBEN, accessed June 29, 2024, https://www.cbenetworks.org/about-the-network.
[4] "Circular Bionutrient Economy Network."

At Manor House to meet the FRN and the SOFDI team.

To Network.

After the meeting, some of the farmers gave us a tour around the center while showcasing some of the projects in progress. We were very impressed by the farmers' innovative ideas for leveraging CBE principles to promote agroecology and seize business opportunities that exist within agricultural value chains. This spanned from using sacks and worn-out car tires for raised bed gardening to the tactical collection of rabbit urine for use as foliar fertilizer. From utilizing vermiculture to valorize organic waste to growing *Azolla* for use as poultry feed. I learned a lot, and I still am, so stay tuned; this is just the beginning.



Top left: posing with Nicodemus and his rabbits. Top left: Nicodemus' tactical collection of rabbit urine. Middle left: raised bed gardening. Middle right: vermiculture (redworms).
Bottom: Azolla

Unlocking the potential of CBE - Mumias.

"Fortune Favors the Bold" - Pliny the Elder.

At the heart of CBEN practices is the Farmer Research Network (FRN) - an innovative network of farmers working together to transform their farming practices, including embracing CBE principles. It's a network where members learn from one another, leaving no one behind towards shared prosperity. The economic reality of many smallholder farmers in Sub-Saharan Africa is that many struggle to make ends meet day-to-day let alone season-to-season, in part due to exorbitant prices of synthetic fertilizers. While synthetic fertilizers often lead to greater yields, they are expensive, frequently inaccessible , and can cause environmental damage that often goes unaccounted for in economic transactions [5]. The dependence on external chemical inputs in Kenya is a bigger systemic problem that must be addressed sustainably.

Meeting some of the members of the FRN in Mumias, Western Kenya.

[5] M. Otoo et al., "Market Adoption and Diffusion of Fecal Sludge-Based Fertilizer in Developing Countries: Crosscountry Analyses" (International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE), 2018), https://doi.org/10.5337/2018.228.

Finding the Secret Ingredients.

The FRN in Western Kenya has embraced CBE with so much enthusiasm, and it's becoming infectious! After a very warm reception, we were given a detailed tour of the different maize plot trials that utilized CBE principles to support maize production and improve soil health. In these plots, "Real Organic" - a fecal sludge-based organic fertilizer made by the farmers from the contents of their pit latrines - was applied during planting, and "Super Gold" - human urine collected by the farmers themselves - was used to top dress. Most of these plots were doing well compared to plots grown without any fertilizer and exhibited comparable performance to plots grown with synthetic fertilizers. FRN's pioneering efforts had begun to show promising results. Not only are they pioneers, but they are also incremental strategists leveraging CBE to address many challenges at once- improved yields and soil health as well as economic sustainability.

Left: Mr. Harun, Farmer Leader, showcasing the "Super Gold". Right: "Real Organic" prepared by Mr. Harun and his team.

From one to two, from two to many, and from many to a thriving network.

Pioneering farmers within the network such as Harun, a Farmer Leader in the region, inspire those around them, who in turn inspire others. To us, this is a perfect example of one of the ways that lasting change happens; the accumulation of power and agency at the grassroots and individual levels [6]. This, and their creative power has even inspired us further to continue strengthening and fostering the relationships between the farmers and other key stakeholders working in the CBE space such as companies and organizations working around the production of organic fertilizers and soil amendments.

[6] Duncan Green, *How Change Happens* (Oxford, New York: Oxford University Press, 2018), chap. 1.

The Mumias FRN.

Shared Prosperity in a People-Centered Economy.

Our efforts draw a lot of inspiration from community-led development and capability approach that aims at enabling people to become agents of change in their own lives and communities [7] For instance, besides helping the farmers set up the "Super Gold" and "Real Organic" field trials, Prof. Midega will be helping them conduct an economic analysis of using "Super Gold" and "Real Organic" versus synthetic fertilizers by calculating the net profit for each approach. We're not the only experts here; a lot of our engagements involve a lot of learning - learning at heart with an action-based mindset that empowers everyone in the process.

Field discussions facilitated by Mr. Harun, Mr. Patrick, Prof. Charles, and Prof. Rebecca.

[7] Severine Deneulin, ed., *An Introduction to the Human Development and Capability Approach*, 0 ed. (Routledge, 2009), chap. 2, https://doi.org/10.4324/9781849770026.

Driven by innovation and action-based research - Black Soldier Fly Larvae (BSFL) Research.

Working with a purpose: turn waste into value

At PHIS you can be involved with almost anything that revolves around agricultural and environmental sustainability, sustainable development, as well as public health. Our work is not just about valorizing organic waste. We engage in multi-dimensional action-based research. It's about public health as much as it is about the environment. It's about nutrient systems as much as it is about food systems. It's about sustainable development as much as it is about achieving sustainable livelihoods and communities.


Left: Prof. Midega, and I collecting pineapple peels within Kisumu City.
Right: Having a light moment at the Circularity and Empowerment Center (CEC).

Seizing opportunities while expanding the good.

One of the CBE projects we're working on involves the bioconversion of municipal organic waste such as fruit and vegetable waste from the market and fruit vendors, into a biofertilizer and animal feed by leveraging the Black Soldier Fly (BSF) technology. Fruit and vegetable waste in Sub-Saharan Africa presents consequential levels of wastage at both the upstream and downstream stages of the supply chain due to poor handling during harvesting and distribution, as well as poor storage conditions exacerbated by their perishable nature [8]. According to a study by Opiyo et al, more than 50% of all municipal waste in Sub-Saharan Africa is composed of organic waste from fruits and vegetables [9]. For instance, the study found that municipal organic waste from the Kibuye Market in Kisumu, Western Kenya - one of the largest markets in East

[8] Emerta Aragie, "Efficiency and Resource Implications of Food Losses and Waste in Sub-Saharan Africa," *Journal of Asian and African Studies* 57, no. 3 (May 2022): 446–61, https://doi.org/10.1177/00219096211020490.
[9] Paul Otieno Opiyo et al., "Urban Dynamics of Food Loss and Waste: Challenges and Opportunities for Improving Food Security in Kisumu, Kenya," *Journal of Food Security*, 2020.

Africa - was mainly composed of spoilt fruit and vegetables [10]. An average of 1214 kg of vegetables and 477 kg of fruits are dumped from the market daily [11]. Valorizing such unavoidable waste including other organic byproducts of the food system such as potato and pineapple peels would have a considerable positive impact on the sustainability of such a food system.

Left: Sourcing pineapple peels.
Right: Collecting potato peels.

"You have to add something to the magic vase for the magic to happen" - John Ruskin.
The BSF Larvae (BSFL) flourish on most organic waste substrates [12]. They consume different organic waste such as municipal organic waste growing into protein-rich biomass and eventually leaving behind a nutrient-rich residue known as frass [13]. The harvested larvae can be used to formulate animal feeds and the frass can be used as a valuable soil amendment. According to Joly and Nikiema (2019), scientists working on organic waste valorization, the BSF-based technology is one of the most promising technologies for organic waste processing and management [14]. The transformation of organic waste via BSF helps to address two major global challenges of food insecurity and waste management and with more attention, it could help close the loop within CBE [15]. Besides researching the quality of BSFL reared on different organic municipal waste streams that are readily available in Kisumu City, we are also exploring how BSF technology can be harnessed to create viable small businesses. Analysis by Joly and Nikiema revealed that the BSF technology could be a promising business opportunity for

[10] Opiyo et al.
[11] Opiyo et al.
[12] Stefan Diener et al., "Black Soldier Fly Larvae for Organic Wste Treatment – Prospects and Constraints," 2011.
[13] G. Joly and J. Nikiema, "Global Experiences on Waste Processing with Black Soldier Fly (Hermetia Illucens): From Technology to Business" (International Water Management Institute (IWMI), 2019), https://doi.org/10.5337/2019.214.
[14] Joly and Nikiema.
[15] Joly and Nikiema.

nutrient recovery from organic waste. This could also help reduce municipal public budget allocations to waste management [16].

Setting up BSFL experiments.

Improving and perfecting the system.

Our next steps involved working with local entrepreneurs/youth self-help groups to support them with the technical aspects of the technology for startups/business development. Logistical challenges of collecting fruit and vegetable waste within Kisumu City for BSF rearing is one of the hurdles we face. To address this we're working on establishing networks with traders and vendors to improve communication and coordination; the integration of convenient transportation means such as a motorbike would make such operations to be efficient and convenient. Nevertheless, revenues from the potential animal feed and biofertilizer could cover some, if not all, of the waste collection costs [17].


Discussions, conversations, planning, and looking looking forward.

[16] Diener et al., "Black Soldier Fly Larvae for Organic Wste Treatment – Prospects and Constraints."
[17] Diener et al.

Nourishment from the world around us.

The biological transformation of organic municipal waste using BSF is more beneficial than other existing options such as landfilling, dumping, open disposal, or incineration [18] - and it promotes some back-end benefits such as improved sanitation and the reduction of pollution and emission of greenhouse gases (GHG) [19].

Preparing substrates for BSFL.

Experimental Design.

Some of the organic market waste we valorized via BSFL technology included peels from common fruits and vegetables such as pineapples and potatoes. We therefore decided to use pineapple and potato peels as some of the substrates to explore. Kisumu is home to East African Breweries Limited (EABL) which produces tons of brewers' waste which we added to our list of substrates to explore. Nevertheless, Kisumu city being a tourist destination, has many restaurants. Even though these restaurants produce loads of restaurant waste from food leftovers, there is a considerable demand from pig farms around. However, there tends to be excessive food waste during the festive seasons. Moreover, the diverse nutrients in restaurant waste would allow us to compare the performance of BSFL on such with the other substrates. With four types of substrates, we prepared six reps for each type of substrate, which was followed by the inoculation of the units with the larvae. Two weeks after the inoculation, the larvae were ready to be weighed. Moving forward, our operations mainly involved tracking the larvae body weights every week for the different substrates. In the end, we would perform a comparative analysis of the growth performance and body weight of the BSFL reared on the different substrates, and the effect of different substrates on optimal growth.

[18] Gromko and Abdurasulova, “Climate Change Mitigation and Food Loss and Waste Reduction: Exploring the Business Case.”
[19] “Circular Bionutrient Economy Network.”


Left: Substrate containers with BSFL (larvaria)
Right: Prof. Midega and Sharon weighing BSFL, Alice recording data

BSFL and BSFL Frass.

BSFL are fascinating creatures; they appear whitish and have a small projecting head with chewing mouthparts [20]. They are voracious feeders and can eat twice their body weight daily, leaving behind BSFL frass - a waste residue made of exuviae, excrements, and leftover substrate [21].


Left: BSFL exuviae
Right: BSFL frass

[20] Andreas Stamer, "Insect Proteins—a New Source for Animal Feed," *EMBO Reports* 16, no. 6 (June 2015): 676–80, https://doi.org/10.15252/embr.201540528.
[21] D. Craig Sheppard et al., "A Value Added Manure Management System Using the Black Soldier Fly," *Bioresource Technology* 50, no. 3 (January 1, 1994): 275–79, https://doi.org/10.1016/0960-8524(94)90102-3.

Poultry Farmers Survey in Kisumu City: Assessing Kisumu Poultry Farmers' Perceptions of Poultry Feeds Formulated from BSFL.

Demand for broiler chicken meat in Kenya is projected to reach 165,000 metric tonnes by 2030 [22]. This projection is raising concerns because limited access to affordable feed is one of the greatest challenges faced by chicken producers; Feed costs account for up to 80% of farmers' total production costs, leaving poor farmers with small profit margins [23]. This has created the need for alternative feed formulations that could substitute the current expensive poultry feeds. BSFL provides a promising alternative source of protein for poultry feed and we wanted to assess the perceptions of the poultry Farmers in Kisumu City towards BSFL formulated feeds.

Left: A poultry farm in Manyatta
Right: Broiler chicken carcasses

We surveyed 3 poultry farms in total; one in Kondele, the other in Manyatta, and the third in Shauri Moyo. Two of the poultry Farmers had switched from expensive feed brands to cheaper brands that produced the same results. The Farmer in Kondele had switched from Sigma feed brand to Pembe whereas the Farmer in Manyatta had switched from Sigma brand to Pembe. On the other hand, the farm in Shauri Moyo specializes in Improved *Kienyeji*-an enhanced breed from the local chicken breeds. To cut down on feed costs, the Farmer preferred to use *Kienyeji Mash*- a mixture of processed grains by-products from the local mills. This is common for small-scale poultry farmers who raise local chicken breeds.

[22] "Monitoring the Nutritional Value of Feed Components for Aquaculture along the Supply Chain – an East African Case Study," accessed April 5, 2024, https://lrrd.cipav.org.co/lrrd21/9/nalw21148.htm.
[23] A. F. B. van der Poel et al., "Unconventional Protein Sources for Poultry Feeding – Opportunities and Threats," 2013, 14–24, https://library.wur.nl/WebQuery/wurpubs/442294.

Poultry surveys in Kisumu City

Conclusion

After a series of data collection, we found out that the type of substrate has a great influence on larvae growth performance and body weight. The results differed significantly across the substrate used. Restaurant waste produced the highest optimal growth, followed by potato peels. The pineapple peels produced average results whereas the brewers' waste had the least output not only in terms of larvae body weight but also the survival rate. Even though the potato peels ranked second, the substrate produced the most promising frass in terms of physical properties.

Left: Restaurant waste/substrate
Right: Brewers' waste

As with any research, certain aspects of the research still need improvement, and more substrates need to be explored. Nevertheless, more studies are needed to validate the potential of BSFL-formulated feed as a potential substitute for conventional poultry feeds.

Left: Sigma poultry feed
Right: Broiler chicken advert in Kondele, Kisumu City.

Acknowledgments

None of these would have been possible without collaboration. With Prof. Charles Midega as the captain of the ship, we had a great opportunity to learn from one another, exchange ideas, and enjoy light moments altogether. A Big Shoutout hereby goes to the amazing team: Sharon, Alice, Cliff, Odongo, and Ken. Special Thanks to Prof. Charles Midega for his mentorship and guidance throughout the process! Thank you our dear readers for being a part of this!

About the author
Jensen Njagi is a senior at Cornell University studying International Development and Development Economics with minors in Global Health and Business. He's a Laidlaw Research Scholar receiving mentorship from Prof. Charles Midega, and Prof. Rebecca Nelson. His research at PHIS and the Nelson Lab is focused on nutrient recovery from organic waste streams for reuse in Agriculture.

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