Low-cost sensors for insect protein production

Pilot Summary

Start Date: September 2021

Completion date: March 2023

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The Problem

As the world population continues to grow, there is a need for alternative sources of animal feed and food to combat the existing challenge of food insecurity across the globe.

The use of insects, particularly the black soldier fly (BSF), is a promising example. Insect protein is a growth industry in Africa, but the potential for local manufacturing of feed using insects is being curtailed due to a lack of technology that can provide the reliable and real time data needed to respond to and optimise growth conditions during the fast life cycle of insects.

The Solution

Led by Sanergy and the International Centre of Insect Physiology and Ecology (ICIPE) in Kenya, this pilot tested if the use of Internet of Things (IoT) technology can provide specific, actionable, real-time data to insect farmers so that they are able to continually monitor insects at all stages of their development.

Specifically, the pilot was designed to see if low-cost wireless IoT sensors could be used to measure pH, temperature, humidity, ammonia, CO2 and pesticide residues; and if that data could be connected to a machine learning system that could guide farmers on how best to rear their insects and increase productivity.

If successful, this pilot would allow insect farmers to monitor their production in real time and effectively and precisely intervene to increase their yields responding to both the data they recieve and the machine learning guidance.

Goals of the pilot

The pilot sought explore a range of key questions, including:

1. Investigate whether sensors can be deployed in Black Soldier Fly Larvae (BSFL) farms in Kenya to generate accurate and reliable data on environmental conditions (specifically pH, temperature, humidity, ammonia, CO2 and pesticide residues)
2. Learn what a longer-term technical product and service model for rolling out the technology across BSFL farms in Kenya would need to consist of. What might the IoT product offering for farmers (i.e. sensors, connectivity, user interface) need to look like, and what additional services would need to be provided to farmers in order to meet all of their needs relating to using the technology for increasing BSFL yields.
3. Validate that a sensor led approach can lead to increased yields in BSFL farms, and begin to develop a machine learning algorithm capable of predicting the effect of different rearing and environmental parameters on yields.

Through delivering against these goals, the pilot aimed to take initial steps towards a longer term vision of creating sensor and service based packages that could be marketed to and scaled for impact with smallholder farmers in Kenya. In this regard, the focus for this pilot was largely on validating that the technology can be adapted to work in BSFL farms and deliver value to end users, and learning what a longer term product and service model for small-scale farms would need to consist of.

Key Activities

The pilot conducted a range of key activities, over the series of four sprints. Broadly this consisted of:

- Deploying IoT sensor networks in both large and small-scale BSFL farms, and monitoring to ensure sensors worked in the context, and could reliably transmit continuous, real time data on environmental conditions.
- Deploying and testing different technical approaches to setting up IoT networks (e.g. deploying multi-sensor nodes as opposed to single-sensor nodes), in order to test which approaches were most contextually appropriate and efficient.
- Conducting user research with small-scale farmers to identify their needs for adopting the technology, before conducting a piloting phase alongside farmers to deploy the technology on their farms, understand their needs, and seek their feedback.
- Developing and training a machine learning algorithm with data collected over the course of the pilot. Data science methods were applied to determine whether the algorithm was capable of accurately predicting the impact of different parameters on BSFL yields. It is intended that the algorithm will be integrated into a product / service offering that can be scaled for impact after the lifetime of the pilot.

Outcomes - key findings from the pilot

The sensor technology can be deployed across BSF is fit-for-purpose, but some design features need to be improved:

Sensors can be deployed across a number of environments (both large and small-scale) such as nurseries, wet larvae grow houses and rearing facilities, in order to relay a range of information in real time, including moisture content of substrate, temperature of substrate, ambient temperature, ambient relative humidity, light intensity and ambient carbon dioxide levels. The sensors developed by the team are capable of reliablying relaying real-time data for the remote monitoring of BSFL at various stages of their development in the substrate. The sensors have a modular design which means they can be used individually, or as part of a bigger node of sensors.

However, some issues pertaining to use of sensors by smallholder farmers need to be addressed if the solution is going to be easy to use and sustainable. This includes the need for calibration of the sensors, which needs special expertise or remote calibration using an online platform. Additionally, internet reliability and battery performance issues suggest that further work is needed to make sensors that reflect the low-tech realities of many smallholder farmers in Kenya.

An enterprise resource planning (ERP) system can be used to create a 'sensor dashboard'

Where multiple users can access the data collected by the sensors. Field data will be able to be accessed by farmers through an Enterprise Resource Planning system and that data could in the future be presented in a manner that was more immediate, accurate and reliable than existing techniques.

The early indications are that a machine learning model can help identify optimum BSF growing conditions, and could play an important role within a wider product / service package for farmers

Pilot testing demonstrated that data models drawing on rearing data can be developed that can predict factors affecting BSFL yields. This demonstrates the potential for machine learning models to be used alongside sensor data to inform recommendations to farmers on what improvements in rearing and environmental conditions could deliver greatest yields.

Smallholder farmers in Kenya can engage with and benefit from IoT sensor technology

Through piloting sensors and dashboards with smallholder farmers, the pilot found that they were able to utilise the technology, and even deliver improved yields based on insights derived from sensors. However, farmers needed support installing and calibrating sensors, and required additional training to use dashboards effectively and apply insights into farming methods. This indicates the likely need for a service based approach to scaling of IoT sensor networks, where in addition to the provision of technical products (sensors, dashboards, Machine learning derived recommendations, etc), services are provided to farmers to help with the use of the technology for impact.

Further work with smallholder farmers is needed to understand needs and refine product / service offering.

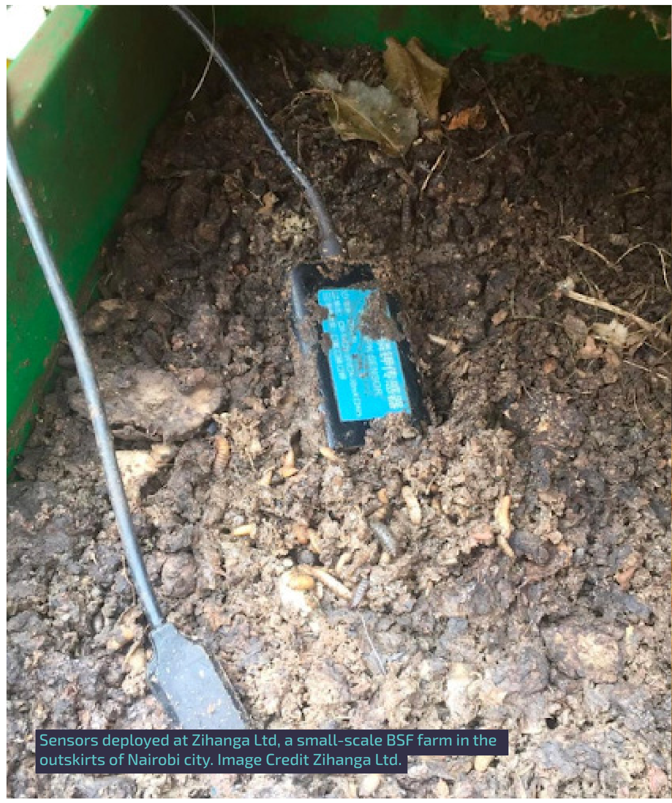
In particular, the pilot didn't manage to present an ERP system that farmers found easy to use and understand. Further work is required to adapt sensors and dashboards to ensure that they are as intuitive as possible for end users, and finalise what the best product package(s) for smallholder farmers need to consist of. An outstanding question is the relative value of different individual sensor types when it comes to yield improvements, and therefore which sensors are most important to include in a product package(s) for market.

Alongside a more refined product package, further work is required to identify what supporting services are required to ensure farmers can extract the most value out of technology (e.g. training, installation/calibration support, maintenance, advisory, financial services).

In order to prepare this solution for scale, a business model also needs to be identified, and wider questions around the viability and feasibility of scaling IoT sensor networks for impact need to be assessed:

Broad questions remain surrounding the viability of a long-term business model to introduce sensors to BSF farmers in Kenya. Once product / service packages have been defined in more detail, further work is required to identify the relative cost of those packages, and confirm that farmers are willing (and able) to pay, have access to appropriate payment models / financial services in order to access the technology, and confirm that investing in sensors can deliver longer term financial benefits for farmers.

In addition to exploring these questions, there's a need to identify what will be required on the supply side from a financial, operational and technical perspective to assess overall feasibility.



Sensors deployed at Zihanga Ltd, a small-scale BSF farm in the outskirts of Nairobi city. Image Credit Zihanga Ltd.

Photo 2: Dried BSF Larvae as an end product of organic waste valorization. Image Credit Zihanga Ltd.