The Locust Innovative Response Initiative (LIRI)

October 2021

photo credit: Alta Innovation

LIRI
White Paper

Alon Gilboa, JDC GRID—Global Response, Innovative Development
Danielle Capalino, JDC GRID Co-Chair
Amnon Levav, SIT—Systematic Inventive Thinking
Hagit Freud, Pears Program for Global Innovation
Sarah Tagger, JDC GRID
Veronica Leifer, JDC GRID
Georgina Campbell Flatter, TomorrowNow
Dr. Yoav Motro, Israel Ministry of Agriculture and Rural Development

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Executive Summary

Over the last two years, East Africa has suffered its most severe locust plague in 70 years, a major disaster that has been overshadowed by the global COVID-19 pandemic. This plague consisted of massive swarms covering vast areas, with each square kilometer containing upwards of 80 million locusts, for an estimated total of some 200 billion insects. Each of these can eat its own weight in vegetation every day, and as these swarms moved across Kenya, Somalia, and Ethiopia, they consumed the equivalent of food for 30,000 people per day, resulting in huge economic losses and widespread food insecurity and threatening the futures of millions of people.

Locust plagues are hardly a new challenge, and their capacity for destruction has been on record since biblical times. Yet remarkably, despite the widespread technological advances of recent decades, no highly effective methods for locust control have been developed that can protect the livelihoods of farmers in a timely and sustainable manner.

For individual farmers, there are no effective solutions available today that can help them proactively prepare for a locust attack and protect their crops. Existing locust monitoring tools are designed to support centralized efforts, such as aerial and ground spraying coordinated by the FAO and public authorities. While these methods are critical for centralized authorities to be able to track and monitor locusts, smallholder farmers remain underserved and unequipped to respond, with women disproportionately affected. In addition, the mass spraying approach has negative impacts on the environment and on pastoralist livelihoods.

To address this issue, **JDC GRID** formed the Locust Innovative Response Initiative **(LIRI)**, together with the **J Gurwin Foundation**, **the Pears Program for Global Innovation**, and **SIT—Systematic** Inventive Thinking. This initiative was based on JDC's longstanding relationships with communities in Ethiopia through the **Tikkun Olam Ventures (TOV)** Program and with various Israeli companies and organizations and draws upon the expertise of the Pears Program for Global Innovation and SIT.

Over the last year, LIRI conducted an intensive process of research and consultation with a diverse group of more than 50 experts from around the world. This process resulted in the identification of five avenues that hold promise for the development of effective solutions for locust control:

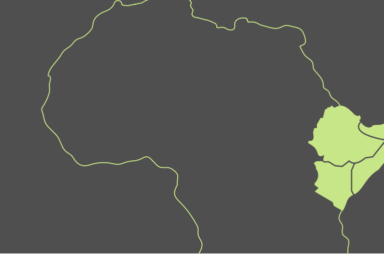
1. Early warning and Action
2. Harvesting locusts as an alternative protein source.
3. Drone technologies.
4. Alternative non-toxic natural repellents.
5. Use of Advanced Weather Intelligence for locust monitoring, control and communication.

LIRI now plans to pilot and assess a response in the second of these five areas (harvesting locusts as protein for animal feed), in a program that combines a deep understanding of needs and conditions in the field with cutting-edge applied knowledge and technology from leading companies and organizations.
This document describes the findings of this research and consultation process and outlines the possibilities for development presented by these five areas, including the pilot program now being executed.

The Problem

photo credit: Alta Innovation

The Problem

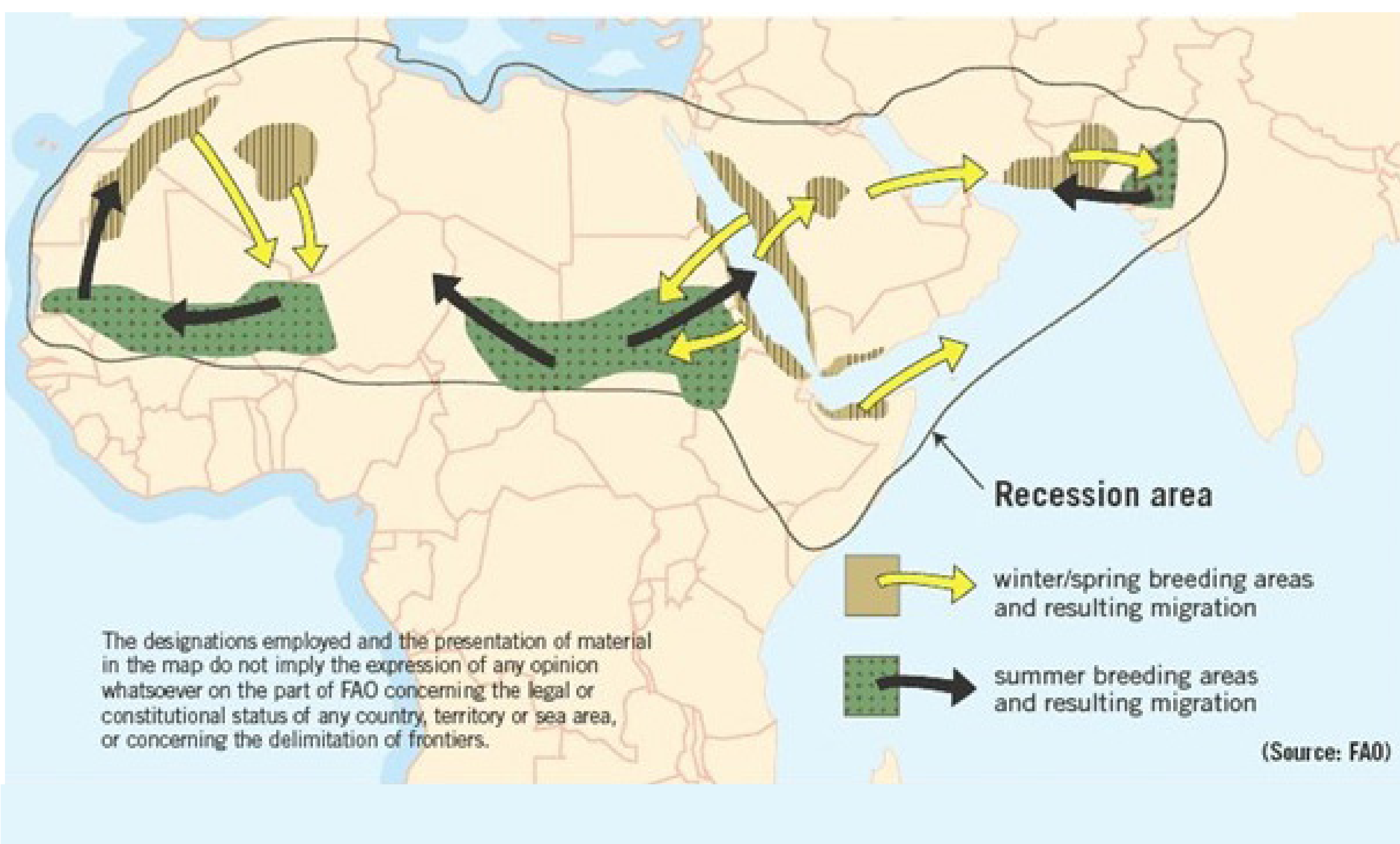


In late 2019, a plague of locusts spread across East Africa. Despite this being the most severe outbreak of the last 70 years, it received little international attention due to the fact that it coincided with the spread of the COVID-19 pandemic.

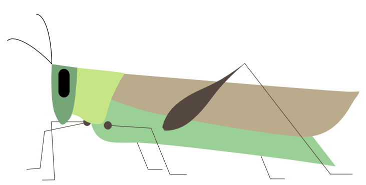
This plague consisted of massive swarms covering vast areas, with each square kilometer containing upwards of 80 million locusts, for an estimated total of some 200 billion insects. Each of these can eat its own weight in vegetation every day, and as these swarms moved across Kenya, Somalia, and Ethiopia, they consumed the equivalent of food for 30,000 people per day, resulting in huge economic losses and widespread food insecurity.

This has had a disastrous effect on 25 million people in the region who now face acute food insecurity, while economic losses are estimated to have exceeded hundreds of million dollars. Though at one stage the situation seemed to be improving, recent weather patterns have led to increased rates of egg hatching, and the crisis has now spread into the Arabian Peninsula and even the Middle East.

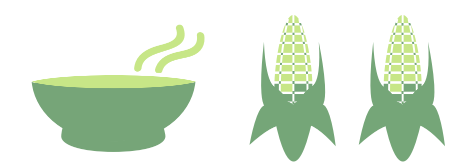
25 Million
People Affected



80
Million Locusts



Consumed crops that could feed
30,000 Per Day



moved across
Kenya, Somalia, and Ethiopia

Our Approach

UAV operation training in Ethiopia – photo credit: Alta Innovation

Our Approach

Our first-hand experience of conditions in the field working with smallholder farmers in Ethiopia through the TOV program made us acutely aware that urgent action was needed to minimize the damage caused by this plague. It was also clear to us that there must be ways to utilize innovative technologies to improve responses on the ground; moreover, given our deep connections both with local partners in the field and with tech leaders in Israel's "start-up nation," we understood that JDC is uniquely placed to draw upon cutting-edge innovation and technology to tackle this enormous challenge.

To this end, JDC GRID created the Locust Innovative Response Initiative (LIRI), which brings together **scientists, experts, innovators, and entrepreneurs** to learn, discuss, brainstorm, and propose new tools and products that can help farmers prevent locust swarms from destroying their livelihoods. To develop LIRI, JDC GRID partnered with the J Gurwin Foundation, the Pears Program for Global Innovation, and SIT–Systematic Inventive Thinking (see Appendix A).
Together, these organizations conducted an in-depth research project, reviewing relevant academic literature and searching for theoretical and applied information regarding the problem itself and current solutions. This work was driven by consultations with a diverse group of experts, including academics, senior figures at various for-profit businesses and NGOs, and officials at the United Nations Food and Agriculture Organization (which is the primary agency currently tasked with addressing locust swarms in the region).

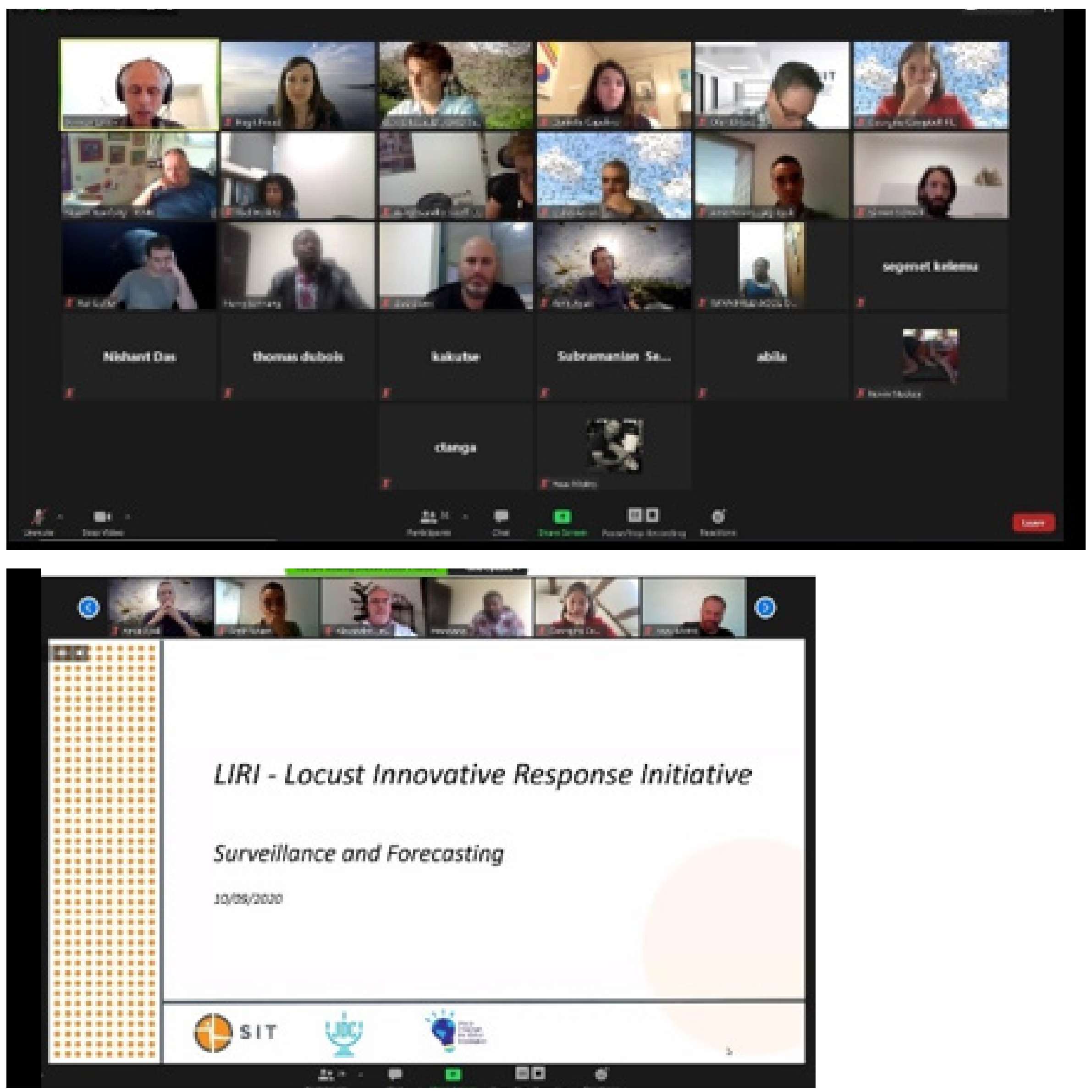
These consultations highlighted the importance of creating innovative and sustainable solutions. Though locust plagues are an ancient problem, and numerous attempts have been (and are being) made to address it, many of the current efforts to provide solutions have had limited success and have high environmental costs. The most widespread solution, which is far from optimal in terms of both effectiveness and financial and environmental sustainability, involves the spraying of pesticides, and is mostly deployed when locusts reach the late stage of maturity. It requires large-scale and expensive operations, which are carried out by national agencies with the support of funding from international institutions.

Most importantly, our team's research made it very clear that **local farmers in Horn of Africa are sorely lacking in tools and resources** to effectively combat locust plagues. This reinforced the message that there is an urgent demand for novel solutions that focus on the needs and capabilities of smallholder farmers.

Our Approach

Five areas of intervention

The initial research process conducted by LIRI resulted in the identification of five main areas of intervention that offer promise for combatting locust plagues. LIRI has identified solutions in each area for further review:



A virtual roundtable discussion with experts, researchers, and practitioners around the world, convened over Zoom by LIRI in September 2020

Our Approach

01

Early warning and action.

surveillance, forecasting and communication. LIRI is in dialogue with companies on how to improve surveillance and forecasting capabilities by using satellite imaging, advanced weather forecasting tools, and GIS tools to monitor and predict the movement of locust swarms. This dialogue is also exploring the possible use of technologies to provide early warning and action system to farmers and ground control units sharing alerts and practical guidance using using SMS/WhatsApp messages and video extension.

02

Harvesting locusts as an alternative protein source.

Locusts can be an excellent protein source for human or livestock consumption, with dry locust meal containing up to 70% protein. Smallholder farmers can be given access to training and machinery enabling them to capture and process locusts for consumption and sell them to local and international markets, to replace income lost due to the destruction of harvests.

03

Drone technologies.

One of the most promising ideas for locust control is using unmanned aerial vehicles (UAVs) equipped with advanced cameras to conduct precise detection and tracking of swarms. UAVs can be used to reach difficult and inaccessible terrain, in which swarms are virtually undetectable by standard spraying helicopters or planes, and they can support ground control units in detection and geolocation, an essential element in nighttime spraying—which is the most effective time for spraying, when locusts are sleeping and immobile. This combination of advanced UAVs and ground control units offers great promise for achieving results over the short term.

04

Alternative non-toxic natural repellents.

LIRI is encouraging biopesticide researchers and product developers, along with funding agencies, to hold trials to assess the practical effectiveness of alternative and biological control methods, including the use of predators and natural repellents. The latter include products from the neem tree.

05

Use of Advanced Weather Intelligence for locust monitoring, control and communication

Locusts are a weather issue, with swarm movement and behavior dependent on the wind direction, cloud cover and temperature; hatching behavior dependent on certain soil moisture conditions, and rapid breeding triggered through extreme weather events such as cyclones. Being able to track, monitor and weather data that dictates locust behavior (such as wind, temperature, precipitation etc) is critical to providing localized warnings and alerts, but must be available at a high enough localized resolution and within a time frame (hours to days) to allow for appropriate planning and action

LIRI in Action Advancing Innovative Solutions

Charles- a farmer from Turkana County in northwest Kenya is feeding the chickens with processed locust - photo credit: Liselott Lindstrom

LIRI in Action - Advancing Innovative Solutions

In the context of the five areas of intervention that were identified, as described above, LIRI has engaged with experts, companies, agencies, and smallholder farmers to identify and advance several practical innovative solutions that hold significant promise in three areas:

Early identification and harvesting locusts as a protein source

For individual farmers, there are no effective solutions available today that can help them proactively prepare for a locust attack and protect their crops. Existing locust monitoring tools are designed to support centralized efforts, such as aerial and ground spraying coordinated by the FAO and public authorities. While these methods are critical for centralized authorities to be able to track and monitor locusts, smallholder farmers remain underserved and unequipped to respond, with women disproportionately affected. In addition, the mass spraying approach is having significant negative impacts on the environment and on pastoralist livelihoods.

During our research phase, our team conducted multiple discussions with experts from around the world in the field of alternative protein sources produced from insects, including leading experts from academia, as well as with innovative Israeli companies active in this field, such as **Hargol FoodTech** Worldwide, there is growing interest in the insect-based protein industry, and the prospect of harvesting locusts for this purpose holds significant promise.

The most promising direction we identified is to complement centralized monitoring and response efforts with a farmer-first system that will (a) ensure that vulnerable communities are informed in time to take simple precautionary actions and protect their farms; and (b) allow for female smallholder farmers to actively contribute to and benefit from the response, through harvesting locusts and reporting data.

The benefits of using locusts as a protein source have been proven to be an

photo credit: Liselott Lindstrom

important source of both protein and income, which are particularly important in areas at risk of famine, such as Madagascar where 400,000 people currently face starvation as a result of the locust. The ability for farmers to extract value from locusts in the form of protein and income was demonstrated through a pilot led by **the Bug Picture** in Kenya where they harvested 4.3 tons of live locusts in 6 weeks and paid over $1,900 to farmers for harvesting. The average farmer household collected 12,000 locusts per night.

This approach is also being proposed as an on-farm complement to locust control. As described in the Conclusion and Next Steps section below, JDC is now launching a six-month pilot program along these lines, in Kenya.

Using unmanned aerial vehicles (UAVs) and precise spraying methods to eradicate locust swarms during nighttime

Current methods used to locate and control desert locust swarms in the region seem to be limited, and have little effect on combating the plague. These methods are mostly reliant on aerial and ground spraying during the daytime. However, the fact that locust swarms migrate during the daytime and move rapidly makes it difficult to monitor and control them. To be effective, spraying methods must be precise and carried out on a large scale by dozens of ground controllers in the field.

During the 2013 locust plague in Southern Israel, a team of experts from the Israeli Ministry of Agriculture (led by Dr. Yoav Motro) gained extensive experience and knowledge in nighttime efforts to eradicate locusts. The unique methods they developed were based on monitoring and controlling the swarms through ground-spraying during the night, when the locusts are at rest, and proved remarkably successful. This approach holds significant potential for tackling the current plague, and also showcases the value of the expertise and technological solutions offered by Israeli organizations and companies.

As part of this solution, unmanned aerial vehicles (UAVs) equipped with advanced cameras are deployed by ground control units to provide detection and precise geolocation of the swarms at their nesting areas, which is essential for nighttime spraying. UAVs can easily reach remote and inaccessible locations, which are virtually impossible to detect using a standard spraying helicopter or plane.

As part of our consultation with leading experts in the field of drones we held multiple discussions with teams at ELTA Systems Ltd., a subsidiary group of Israel Aerospace Industries **IAI** and learned that they are developing drones that will be able to lift significant weights of between 50kg and 100 kg and remain airborne for several hours. Such drones could potentially be used for precise spraying from the air, in order to complement more traditional ground and air spraying efforts. This combination of well-trained ground control units equipped with advanced Israeli UAV technologies is probably the most effective method for combatting swarms in the short term.

Israeli Government Support: Training Seminars and Field Operations

In November 2020, the Israeli Ministry of Foreign Affairs sent a team of experts led by Dr. Yoav Motro to Ethiopia to conduct training seminars in the country's highly affected Somali region in Ethiopia. They provided instruction to 100 regional field controllers from Ethiopia's Ministry of Agriculture on effective and safe nighttime spraying, including reading UAV maps, calculating wind speed and direction, and operating vehicle-borne and backpack sprayers using environmentally friendly materials. In addition, professional training and guidance was provided for 30 UAV operators, who learned how to pilot the UAVs and how to locate and track locust swarms to mark roost sites for night spraying.

In addition to these training activities, the Israeli Ministry of Foreign Affairs donated to the Ethiopian Ministry of Agriculture a consignment of 30 UAVs for tracking and mapping locusts. This equipment and training was designed to create the basic infrastructure for continuing efforts to control locust swarms using UAV tracking and night spraying, with the hope that these efforts will be expanded in the future. The drones donated by the Israeli government are ready for deployment in Ethiopia and could be potentially used for locust tracking or other agriculture-related purposes. This will require continued funding and support for implementation from local and international entities.

LIRI in Action - Advancing Innovative Solutions

In April 2021, multiple groups of mature and larval locust invaded Israel in the Arava region for a few weeks. During this period, cooperation between the Israel Ministry of Agriculture and Rural Development (IMARD) and the UAV company Alta Innovation, conducted experiment with novel UAV applications **for scanning and spraying** of both mature and larval locust. In this experiment a large 25kg precise sprayer UAV was tested using two insecticides, namely: Pyrethrum and Cypermethrin, which were found effective in eradicating locust within an hour after application. This experiment indicates that a spraying drone can effectively cover dozens of hectares per day while avoiding waste of pesticide and reducing harm to the environment.

photo credit: Alta Innovation

Alternative non-toxic natural repellents

Non-toxic natural repellents, also known as biopesticides, have proven effective on pests across global ecosystems. However, there has been limited research on their use against locusts. As a result, a number of biotechnology companies (such as Koppert Biological Systems) are currently running trials in order to assess the viability of biopesticides for treating locust infestations. One fungal compound in particular, **metarhizium acridum**, shows promise in that it has had initial success in treating other pests by slowing their growth cycles. [1]However, additional research is needed to assess the efficacy of this product against locusts.

Like traditional pesticides, most biopesticides can be sprayed via aerial application or terrestrial application; however, though biopesticides are safer than their chemical counterparts, they often take longer to become effective. This is because they work by slowing or stopping the growth cycles of the insect, rather killing them on contact. Again, further study is needed to determine whether the timeframes involved are too large, in terms of the quantity of crop damage caused before the number of pests is reduced.

According to some experts the neem tree presents a promising alternative because of its multitude of applications. [2]Firstly, the trees themselves can grow within a few years to serve as natural barriers that protect crops from locust swarms. Secondly, neem tree oil can be extracted and sprayed on crops as a protectant. [3]The neem tree has also been noted for its varied medicinal and cosmetic qualities, such that growing these trees may have the added benefit of providing farmers with opportunities for localized economic initiatives.

To develop a response to locust swarms based on the use of biopesticides or non-fungal products such as neem oil, the best course of action would be to assist in piloting existing products from biotechnology organizations that are currently conducting research trials on alternative repellents.

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[1] *Michel Ruan dos Santos Nogueira et al., In vitro efficacy of two commercial products of Metarhizium anisopliae s.l. for controlling the cattle tick Rhipicephalus microplus, Brazilian Journal of Veterinary Parasitology 29, no. 2 (2020),* www.scielo.br

[2] *Saleem Ahmed and Michael Grainge, Potential of the Neem Tree (Azadirachta indica) for Pest Control and Rural Development, Economic Botany 40, no. 2 (April–June 1986): 201–209,* www.jstor.org

[3] *Martin Baumgart, Effects of Neem (Azadirachta indica L.) Products on Feeding, Metamorphosis, Mortality, and Behavior of the Variegated Grasshopper, Zonocerus variegata (L.) (Orthoptera: Pyrgomorphidae), Journal of Orthoptera Research, no. 4 (August 1995), pp. 19–28,* www.jstor.org

Use of Advanced Weather Intelligence for locust monitoring, control and communication

Our ability to monitor and control locusts has been severely limited by the lack of localized and timely weather forecasts available in remote areas most at risk. Locusts are a weather issue, with swarm movement and behavior dependent on the wind direction, cloud cover and temperature; hatching behavior dependent on certain soil moisture conditions, and rapid breeding triggered through extreme weather events such as cyclones. Being able to track and monitor weather data that dictates locust behavior (such as wind, temperature, precipitation etc) is critical to provide localized warnings and alerts, but must be available at a high enough localized resolution and within a time frame (hours to days) to allow for appropriate planning and action. Poor weather infrastructure in Africa has prevented weather intelligence organizations from achieving this necessary resolution and on time action. There exist well known challenges associated with absence of functioning ground stations, poor geospatial coverage and affordable models for dissemination. As a result, most locust advisory reaches farming communities after the event, if at all, with not in enough time or information to enable coordinated action; During this crisis, innovative solutions started to emerge; Advancements in predictive modeling capabilities now improve emerge such as the ones developed by **Tomorrow.io** the resolution using complex techniques; Tomorrow's also have improved capabilities for sourcing and integrating non traditional data sources including underutilized ground stations and external data sources to enhance quality of localized forecasts; Innovative experiments were also run to leverage citizen science as a means for ground truthing.

The real opportunity now is in combining these data sources such as pairing real time forecasts with citizen ground observations, and enhancing the digital infrastructure for communicating alerts on time, as well as shaping the partnerships necessary for ensuring these innovations have business models that allow for sustainability and can be publicly accessible long term for those most in need.

Investments are also essential in the fundamental infrastructure to improve data inputs.

Investment in weather innovations will enhance the ability to forecast movement, communicate action and enable a more proactive response to the desert locust, such as:

Hatching index - using a combination of soil moisture data, and advanced models, weather prediction tools can identify remote areas, and do targeted control such as localized spraying or more traditional nature-based methods such as soil digging at scale.
Locust swarm tracking - using advanced modelling techniques and leveraging the latest input data, we could provide <1km real time and forecasted alerts to help ground teams be more targeted with their spraying, and local people to take practical actions such as covering water to prevent contamination from droppings or early harvesting.
Tools for real time tracking and rapid dissemination of alerts and guidance via mobile - established Saas infrastructure (mobile, APIs, dashboards) can be paired with localized weather alerts and knowledge of actions that can be taken to rapidly communicate to farming communities and ground teams, enabling inclusive reach of alerts and actions to take place in time to make a difference

Tomorrow.io is an Israeli founded company and is investing heavily in innovations to improve locust monitoring and communication as part of a larger effort to help individuals, businesses and governments to manage weather and climate risk with advanced weather data and tools. They also have a non profit, **TomorrowNow.org** which is focused on the systemic changes that need to happen now to improve quality and inclusive usage of weather data and tools and enable inclusive climate action for the 5 billion currently underserved by traditional approaches.

Conclusions and Next Steps

photo credit: Alta Innovation

Conclusions and Next Steps

Numerous attempts have been and are being made to address the problem of locust swarms. These have included experimentation with biological pest control; research on locust hormones, locust genome sequencing, and locust sensitivity to scents; various applications of drones and of lasers; and more.

Although a surprisingly large number of research projects and initiatives have been launched during the past 50 years, most do not even reach the pilot stage in Sub-Sharan Africa.

Over the course of a year and a half, the LIRI team has extensively researched the issue and held in-depth discussions with world-leading experts from various fields in order to inform our strategic direction. By means of this process, with particular focus on the topics described in the previous section, the team was able to identify a number of areas worthy of further exploration that may provide the foundations for future initiatives (see Appendix B).

While most of the exploratory projects and initiatives we learned about did not reach the pilot stage, these efforts represent a plethora of options could be further developed into successful solutions, if properly resourced.

Based on the outcomes of these efforts and current opportunities for collaboration, we have decided to focus on one potential initiative.

photo credit: Alta Innovation

Conclusions and Next Steps

LIRI Pilot Program in Kenya

The LIRI team has identified a first-of-its-kind prediction and early warning solution that focuses on creating meaningful value from locust harvesting for small-scale female producers. Based on the findings of our research and consultation process, JDC decided to work with four selected partners, and in August 2021 we launched a six-month pilot program in Kenya, driven by Israeli weather forecasting technology. This technology will be deployed to provide female farmers with early warnings of approaching swarms and present them with recommended actions.

The pilot will be based on contributions from the five selected partners:
TomorrowNow.org, a non-profit focused on inclusive climate action, leading the coordination of pilot activities and stakeholders.
Kenarava Group Ltd bringing the voice of the farmer into the solution design.
Digital Green's farmer-first multi-channel digital extension approach;
and **The Bug Picture's** substantial knowledge and information on harvesting and processing desert locusts. By combining these resources, the pilot is designed to create a robust and highly innovative, cost-effective, and inclusive climate action system for use by female smallholder farmers, extension workers, and government planning offices at both the regional and national level. The locusts harvested by farmers will be processed and sold via local markets to vendors of feed and compost, using market linkages provided by The Bug Picture. The entire process will be captured and documented by short video clips that could be translated to different languages and digitally distributed to other communities.

If it proves successful, this project offers a model that can then be replicated in the future in other areas under threat from locust swarms, offering a response to this threat for smallholder farmers by mitigating the plague damage in a financially sustainable and environmentally friendly manner.

photo credit: Liselott Lindstrom

Female coordinator records sacks of desert locusts harvested during the night, before delivering them to the local market to sell for animal feed. This night-time harvest produced approximately 250kg.

Conclusions and Next Steps

Additional Avenues of Intervention

LIRI is also looking to advance the development of other solutions, including the use of UAVs (as noted, some basic infrastructure for this already exists in Ethiopia), and applications of alternative non-toxic natural repellents.

By developing and implementing cutting-edge solutions that combine Israeli innovation with a deep understanding of the needs and capabilities in the field and disseminating the applied knowledge gained to as many communities as possible, we hope to bring an end to the locust crisis in East Africa and help avert such crises in the future.

photo credit: Alta Innovation

Appendices

Appendix A: LIRI Partners

LIRI was partially funded by the **J Gurwin Foundation**, and included the following partners:

JDC GRID

is the disaster relief and international development arm of JDC. When natural disasters or other calamities strike, we help communities of all backgrounds and faiths rebuild. We tackle big problems and aim to a have a long-term impact, through the creation of sustainable partnerships with local and international organizations. We harness Jewish and Israeli innovation, technology, resources, and expertise to respond to crises and severe deprivation around the globe, thus helping the world's most vulnerable populations while strengthening ties with Israel and the Jewish community.

The Pears Program for Global Innovation

is a not-for-profit and nongovernmental organization whose mandate is to increase Israel's contribution to international development and humanitarian aid through technology and innovation. The program believes in the transformative power of technology and innovation to improve the lives of people all over the world, and is dedicated to building bridges between the Israeli innovation ecosystem and the developing world.

SIT–Systematic Inventive Thinking

is an Israel-based consulting company with its own proprietary approach to fostering innovative thinking, now used in 74 countries. SIT offers programs that help organizations develop the culture and practices through which innovation thrives.

Appendix B: Areas Worthy of Further Investigation

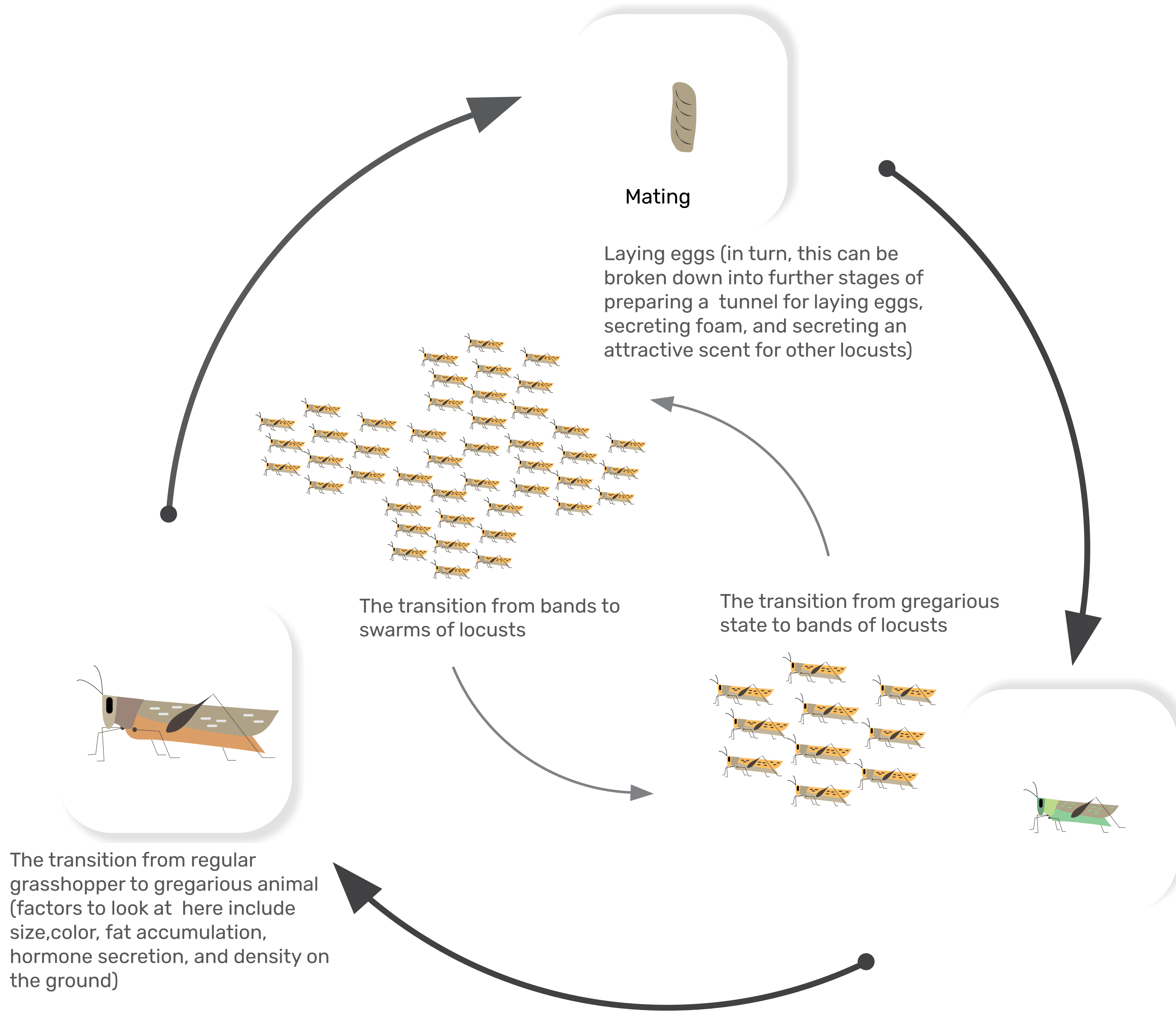
The research and planning process described above was facilitated by SIT, an organization that specializes in creative methods for thinking about problems and coming up with breakthroughs and innovative solutions. The approach used with LIRI was to deconstruct “the locust problem” into a nested series of smaller and smaller sub-problems.
Once these are mapped out, they can each indicate one or more areas or topics in which to search for and come up with solutions.

Since real-life problems are typically complex and multi-faceted, as is the case with the locust challenge, the overall solution will often be composed of several solutions, resulting from the exploration of more than one area or topic. This is a further advantage of this approach, as it encourages continued work until multiple solutions have been found, and then testing them and integrating the most promising options into a comprehensive solution.

The following areas for further investigation were identified, ordered here into five main categories:

From Grasshopper to Plague

Within this category, the first area to explore is that of the locust life cycle, which comprises five main stages:



Life cycle infographic Credits: NRT

The second area worthy of investigation is the migration, movement, and navigation of locust swarms. Relevant topics include:

Using attributes of locust navigation to forecast size and direction of swarm

Options for interfering with navigation

Containment in specific areas

Predators as markers of locust location

Using scent-control to interfere with communications

The third area in this category is examining the impact of **weather and of other environmental and geographical conditions**. These investigations could be used to forecast the movement and size of swarms, or could produce options for redirecting or disrupting swarms by manipulating weather parameters. Additionally, it might be possible to create conditions that would strengthen the presence and impact of locust predators.

Locust Control

The first area for investigation that presents itself with regards to locust control is the use of pesticides.
This would include looking at the types of pesticide used previously or currently to combat locusts and/or other pests, and to explore potential new developments. It would also include topics relating to the availability of pesticides (manufacturing issues, costs, access) and to the delivery of pesticides on the ground (whether aerial or non-aerial, including the use of drones or other devices). In addition, there is the associated topic of how to mitigate the adverse effects of pesticides.

The second area is that of biological methods for controlling locusts, in which investigations could look at past attempts and the insights they produced, as well as potential new biological solutions, with possible lessons from efforts to prevent the collapse of bee populations.

The third area for further investigation in this category is that of additional optional methods for locust control, which include applying traditional methods (such as digging ditches), possibly in combination with novel technologies; utilizing seemingly unrelated novel technologies; and using predators to control locust populations.
Fourth, there is the topic of the logistics involved in deploying solutions, which need to be addressed before solutions are delivered. This includes studying and understanding current problems and challenges, and exploring potential alternatives.
The fifth and final area is that of the various training aspects involved in deploying solutions, including instructing professionals in the proper usage of those solutions, and training local users to ensure long-term self-sufficiency.

Appendices

Locust vs. Plants

This third category concerns possible solutions that relate to the direct interaction between locust and plant. The areas for further investigation include possibilities for interfering with locusts landing on plants, interfering with their eating of plants, disrupting locusts leaving plants, and modifying plants so that they protect themselves.

The Farmers' Perspective

The first area within this category involves analyzing the farmers struggle with locusts. It includes:

1.Learning and using traditional methods (see category 2 above)

2.Understanding farmers' positions with regards to current methods (such as pesticides)

3.Understanding the barriers and challenges facing farmers with regards to deployin existing methods, or any future methods

The second area relates to understanding the impact of locusts on farmers' lives and work, including economic effects, impact on family life, and impact on their communities.

The Global Perspective

The final category moves beyond topics relating directly to the locusts themselves, and beyond the farmers' viewpoint, to consider a broader global perspective.
The topics in this category include:

- How to improve systems and techniques for monitoring, detecting, forecasting, and alerting

- Political, organizational, and budgetary issues

- Meta-solutions:
How to create the most effective mechanisms for solving the problem, involving multiple partners, sponsors, and experts, and considering aspects of motivation, coordination, and resource pooling