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ALLIANCE TO FEED THE EARTH IN DISASTERS

The Potential for a Novel Financial Product to Safeguard Communities Against Future Locust Outbreaks

A scoping, financing, and implementation overview

High-level Guidance Document

November 2021

CONTENTS

Executive Summary

As part of ongoing efforts to expand resilience finance across Africa, we propose the creation of a novel financial product targeting locusts in the Greater Horn of Africa, which will allow a quick and effective response to any future outbreaks across the region.

Once established, this product would deliver a fast response to a future locust outbreak as soon as it is detected and the triggers attached are met.

However, unlike traditional insurance, the proposed mechanism would pay to the affected areas as control operations to suppress the outbreak rather than in cash, with the payout used to fund these operations. These services would be procured in advance, and once needed would be coordinated by the FAO in line with recent effective practice and their guidelines.

This would solve two fundamental problems with the current response structure to locusts:

- As capital would be secured in advance, **a pay-out could occur as soon as the threat from swarming locusts is detected, rather than after rounds of fundraising.**
- As control operations would have been procured in advance **a response can begin as soon as possible, rather than having to wait for bids to be processed and contracts agreed.**

These two elements are particularly vital in the case of locusts, where swarms breed exponentially and delays of months or even weeks can mean a massive increase in the problem at hand. As a result, the locust financial product would be expected to significantly reduce the overall cost of a future intervention, as well as the damage the next locust outbreak causes.

However, in order to launch the product we need support from donor organisations active in the Horn of Africa, alongside contributions where possible from local countries and other partners. Given the nature of the threat from locusts, it is expected that these contributions will in turn reduce long term costs for donors by reducing the severity of future locust outbreaks, shifting to a preparatory rather than purely responsive model.

The locust financial product could be structured as either an insurance product, or a catastrophe bond. We would expect that the total payout would be around US$33 million under our base assumptions, with an annual coupon/premium of around US$3.5 million. This is based upon the average of recent costs of locust surveillance and control operations as well as chemical procurement, however the total capital and coupon payments will only be known once the bond/insurance is issued.

In return for these coupon payments, donors and the countries in question would get control operations covering around half a million hectares, which would be delivered as soon as contractors are able once the next outbreak is detected.

This would significantly reduce the risks associated with locusts, and also be expected to both reduce the costs of the next intervention. Finally, the establishment of the locust financial product would reduce the damage swarms cause to livelihoods across the region, potentially with a tenfold return of the value of food safeguarded versus its cost based upon the effectiveness of recent control operations, even before the benefits of an earlier intervention are taken into account.

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In addition to this white paper, there is also another paper produced by ALLFED on the potential of UAVs to build resilience against future outbreaks. Their deployment would strengthen the product by lowering the cost of a future response, which would in turn reduce the annual coupons (which we discuss in detail at the end of Section 2 below). If you have any questions on the potential uses of drones in a future outbreak please contact the report's author, Noah Wescombe (noah@allfed.info).

Section 1: Introduction to desert locusts

Locusts are grass-eating insects, commonly found in arid regions of Africa, and South/South West Asia. During upsurges and outbreaks these insects, especially desert locusts (Schistocerca gregaria), can form large swarms that can threaten entire agricultural economies.

Typically, locusts are solitary and are spread out across remote arid and semi arid regions. In this form they are broadly harmless, and are unable to fly or cross large distances.

However, when conditions are wet enough, locusts can breed beyond the ability of their original habitat. This triggers a physiological change in the locusts to a "gregarious" phase, where they grow wings and begin to swarm in order to find new sources of food[1]. These conditions for swarming have occurred once every 10-15 years in the past, however there is evidence that the frequency of events may be rising due to climate change leading to higher volatility in rainfall.

Under these optimal climatic conditions, locusts breed fast and swarms can reach sizes of up to 460 sq miles with 40-80 million insects packed in half a square mile. A locust can eat its own body mass in plant matter daily, meaning that a large swarm can eat around 160,000 tonnes of food in a single day, destroying crops, trees and any vegetation in its way. This has enormous consequences for the countries in a number of regions, particularly Africa, which has an extensive agrarian economy. Loss of crops there leads to food insecurity, lower exports, and sometimes famine in past outbreaks.

Based upon these dynamics, the FAO divides locust population dynamics into four periods[2], quoted below:

1. **The recession period** in which the desert locust has a low population density and is found in arid and semi-arid areas, i.e. the permanent habitat areas, that are distant from the main agricultural regions. It does not cause significant damage to crops, and hopper bands and swarms are completely absent.
2. **The outbreak period** corresponding to a significant increase of the number of locusts for several months due to their multiplication, concentration and transformation, which, if not controlled, can lead to the formation of small hopper bands and winged groups, even small swarms. The infestations remain localized.
3. **The upsurge period**, which is the result of successful breeding over several generations by the initially small populations. In each generation, the desert locust population as well as the size and cohesion of hopper bands and swarms increase. They move and cover increasingly larger areas, generally within a single region, as the upsurge develops.

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[1] Cisse, S., Ghaout, S., Mazih, A., Babah Ebbe, M.A.O., Benahi, A.S. and Piou, C. (2013), Effect of vegetation on density thresholds of adult desert locust gregarization from survey data in Mauritania. Entomol Exp Appl, 149: 159-165. https://doi.org/10.1111/eea.12121

[2] INSTITUTIONAL STUDY TO ENHANCE THE ROLES AND RESPONSIBILITIES OF THE DESERT LOCUST CONTROL COMMISSIONS ESTABLISHED UNDER ARTICLE XIV - 2011 http://www.fao.org/ag/locusts/common/ecg/2148/en/Financial_Governance_Report_E.pdf

4. **The plague period** corresponding to a period of one or several years of serious and widespread infestations of hopper bands and swarms. A widespread plague occurs when two or several regions are simultaneously affected.

Locust outbreaks occur at a frequent rate, but the conditions for upsurges are rare and involve multiple dynamic variables that are only seen about once every decade. Meanwhile locust plagues have not been seen since the 1960s, due to advances in control operations and surveillance.

Recent generations of locust swarms are most frequent in the Arabian Peninsula, the African coast of the Red Sea, and the coast of Iran. Previous data on generation presents a close correlation of favorable climatic conditions to the Tropic of Cancer. Areas such as the Empty Quarter in the south of the Arabian Peninsula collect and isolate water from storms into ponds in the landscape, which are then warmed by weather conditions. This provides ideal conditions for desert locust eggs to hatch. However, regions in North/West Africa have also been breeding grounds (Map 1).

Map 1: Desert locust recession (blue area) and potential plague (orange areas) distributions [3]

[3] Showler, A.T, and C.S Potter 1991 Synopsis of the desert locust, *Schistocerca gregaria* (Forskal), plague 1986–1989 and the concept of strategic control American Entomologist 37:106–110.

The vast area where locusts can breed, combined with varying resources, geographical conditions and security situation across these zones, makes long term management of locusts very difficult. Swarms can form undetected as a result and migrate long distances during upsurges and outbreaks, suddenly placing previously untouched regions at risk at short notice.

As a result, any viable long term strategy to combat locusts must be coordinated at least partially at a regional level, as their costs will initially be borne by the frontline countries, whose effective control operations provide protection for their neighbours.

As a result of this regional element, much of the response to locusts across Africa is now coordinated by the FAO, which also consults on fertiliser authorisation, arranges fundraising as local resources are often insufficient, carries out procurement and directs control operations.

With improvements to locust spraying, swarm tracking as well as ongoing support for farmers devastated by locusts, the effectiveness of locust control has been rising in recent years. However, significant issues remain. In particular the unpredictable nature of upsurges lead to delays in response efforts. The resources needed to respond to locusts are significant meaning that control operations can begin, fundraising must occur, and then the additional resources and personnel must be procured. This presents a problem for locust management given their exponential population growth, and raises the total costs of a response and the damage caused by swarms.

The 2003-05 locust outbreak across West Africa cost US$450 million to end, while the 2019-21 outbreak across the Greater Horn of Africa has cost upwards of US$600 million so far, with crisis appeals still ongoing to fill multi-million dollar funding gaps. However, the damage caused and the cost of the intervention could have been reduced through early action, which is the aim of our proposed financial product.

Forms of interventions

Locust interventions take a number of forms, depending upon how early the swarm or risk of swarming is detected, the remoteness and security situation of the area locusts are present in, and the resources available. The types of interventions can be divided into three categories[4], and it is possible to have an intervention that covers several of these categories as a continuum, as a swarm forms, breeds and progresses.

Reaction

Reaction refers to defensive operations taken to protect economically and socially important areas while swarming behaviour is underway, focusing efforts around high value farmland rather than intervening against locusts breeding in remote regions. This is ideally combined with insurance and support for crop losses where

[4] Showler, A.T.; Ould Babah Ebbe, M.A.; Lecoq, M.; Maeno, K.O. Early Intervention against Desert Locusts: Current Proactive Approach and the Prospect of Sustainable Outbreak Prevention. *Agronomy* **2021**, *11*, 312. https://doi.org/10.3390/agronomy11020312

they occur. However, given limited local budgets, weak access to insurance and other forms of risk management and the small scale nature of many of the farms impacted, this has significant challenges in reality.

Reaction is the cheapest form of intervention in direct spraying costs, and requires only limited surveillance resources and sophistication. However, it also can carry the highest crop losses, and as locusts are not targeted beyond areas of human habitation swarms can breed rapidly and persist for extended periods if conditions in remote areas are supportive.

This means that under reaction, outbreaks have the potential to last far longer and cause far more damage than with other earlier forms of interventions, potentially with higher direct intervention costs and crop losses as a result. These impacts often fall heavily on small scale farmers, who are often on the most marginal land and where reaction is hardest, magnifying the social damage of economic losses. In addition, locust damage to more remote regions is not costless, and can disrupt pastures and livestock cultivation across wide areas[5].

As a result, most countries have tried to move away from a purely reactive approach to locust management, though reactive measures may still be necessary should outbreaks exceed the ability of other approaches to contain their spread.

Proaction

Proaction refers to active measures taken to contain and disrupt swarming locust populations before they breed out of control and move into economically and socially valuable areas[6]. This requires accurate swarm tracking from both the ground and air depending upon the terrain, sufficient spraying resources both in terms of chemicals and aircraft, and coordination of the surveillance and spraying teams due to the migratory nature of locusts[7].

As a result, the resources and sophistication required for proaction are higher compared to a purely reactive approach, however given the exponential growth possible with locust swarms in remote areas, final costs (particularly crops losses) can be much lower.

The forms of proactive interventions have changed over the years, due to improvements in monitoring, new spraying techniques and products, as well as political changes and a rise in regional cooperation in many impacted areas. The effectiveness of proaction relies upon the early and accurate location and suppression of breeding areas, with historical performance strongly suggesting that the longer gregarious swarms are allowed to

[5] Belayneh, Y.T. Acridid pest management in the developing world: A challenge to the rural population, a dilemma to the international community. J. Orthopt. Res. 2005, 14, 187–195. https://www.jstor.org/stable/3657127
[6] Showler, A.T. Proaction: Strategic framework for today's reality. In New Strategies in Locust Control; Krall, S., Peveling, R., Ba Diallo, D., Eds.; Birkhauser: Berlin, Germany, 1997; pp. 461–465.
[7] Showler, A.T. A summary of control strategies for the desert locust, Schistocerca gregaria (Forskål). Agric. Ecosyst. Environ. 2002, 90, 97–103

initially breed unhindered, the worse the risks become[8 9]. As a result, early detection and early deployment of resources is vital in reducing the impact of locust swarms under a proactive approach.

Outbreak Prevention

Outbreak prevention refers to early actions taken to prevent gregarious behaviour and swarming in the first place, by active monitoring of at risk zones and immediate actions based upon risk factors, such as rises in hopper numbers, nymphs beginning to clump, or the occurrence of a weather shock optimal for locust breeding[10]. Once detected, spraying is carried out to reduce populations to standard levels, preventing pheromone cues and swarming behaviour from occurring. Not every one of these events would have resulted in a locust outbreak if untreated, however outbreak prevention efforts can significantly reduce overall costs of locusts, by effectively containing populations at sustainable levels[11].

Outbreak prevention requires constant monitoring of all at-risk zones, which are geographically large and difficult to access by their nature. These zones are also sometimes located in areas with other challenges, such as parts of Yemen and Somalia where the security situation can disrupt attempts to monitor and respond to early signs of swarming. Outbreak prevention therefore is not always possible due to the situation on the ground, and requires an ongoing commitment of resources from donors or the countries in question in order to be sustainable.

The current status of interventions in the Greater Horn of Africa

The Greater Horn of Africa (defined here as Ethiopia, Kenya and Somalia, the most at risk countries in the region which are the focus of our proposed bond, which would also protect Djibouti and parts of Uganda and Tanzania) is only partially within the habitat of desert locusts during recession periods (Map 1), which covers North-East Ethiopia, limited parts of Kenya and most of Somalia. However, during upsurges and outbreaks (which commonly originate outside of the region) the Horn of Africa is at a high risk of crop losses, with the majority of Ethiopia, Kenya and Somalia exposed to locusts during upsurges and even parts of Uganda and Tanzania at risk of rogue swarms.

During locust recessions, the region already engages in a range of monitoring and suppression measures (although these are small in scale compared to neighbouring countries where locusts habitats during periods of remission are far larger):

[8] Sword, G.A.; Lecoq, M.; Simpson, S.J. Phase polyphenism and preventative locust management. J. Insect Physiol. 2010, 56, 949–957.

[9] Lecoq, M. Recent progress in desert and migratory locust management in Africa: Are preventative actions possible? J. Orthopt. Res. 2001, 10, 277–291.

[10] Showler, A.T. Desert locust control: The effectiveness of proactive interventions and the goal of outbreak prevention. Am. Entomol. 2018, 65, 180–191.

[11] Babah, M.A.O. Brief overview on the desert locust problem. Tunis. Plant Prot. J. 2011, 6. Available online: https://www.jircas.go.jp/sites/default/files/publication/proceedings/2012-session-41_0.pdf

- In typical years, locust populations are monitored and sprayed within their borders, as part of a proactive/outbreak prevention strategy. Total spraying in these activities ranged between 0-6,000 annually hectares between 2007 and 2016, with periods (2010-2012 and 2015) where no significant populations were detected and spraying was minimal.
- The majority of spraying occurs within Ethiopia, where the North East part of the country in particular has conditions suitable for locust breeding.
- Much of Somalia is also suitable for locust breeding, however control operations there are far more limited.

Meanwhile, neighbouring countries where locust habitats are widespread also engage in widespread spraying, covering just over 125,000 hectares annually from 2007-2016 (Diagram 2). These operations have varied depending upon the levels of locusts detected, but also importantly on the security situation and funding of the countries in question.

Diagram 1: Locust control measures in the Horn of Africa, 2007-2016[12]

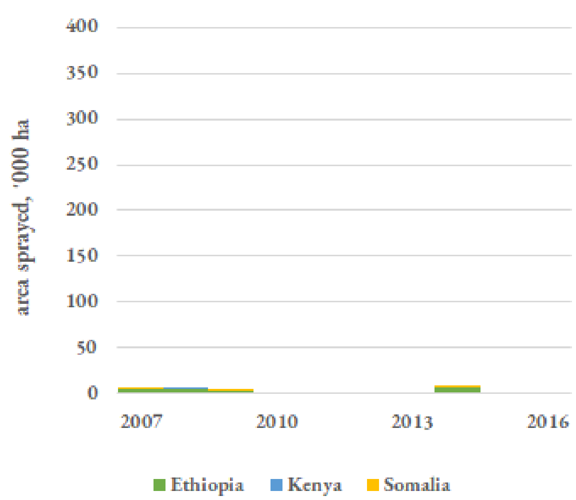
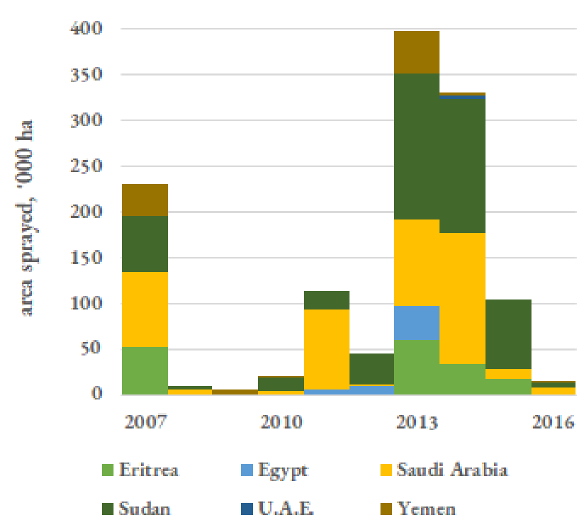


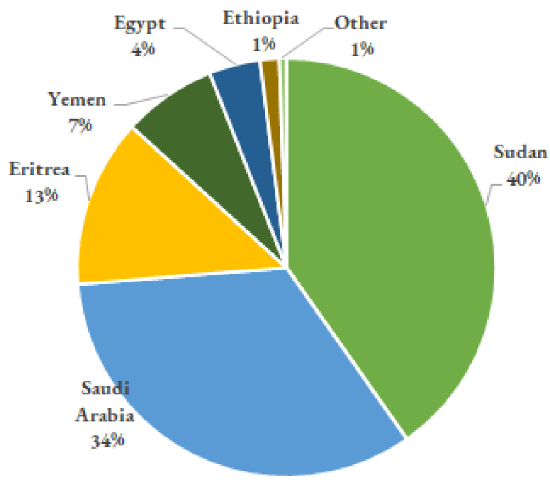
Diagram 2: Locust control measures in neighbouring countries, 2007-2016



[12] Allan T Showler, Desert Locust Control: The Effectiveness of Proactive Interventions and the Goal of Outbreak Prevention, *American Entomologist*, Volume 65, Issue 3, Fall 2019, Pages 180–191, https://doi.org/10.1093/ae/tmz020

Challenges with existing locust management

Diagram 3: Locust control measures in and around the Horn of Africa by country, 2007-2016



While it must manage its own locust breeding zones on an ongoing basis, the Horn of Africa is also highly exposed to plagues originating from outside of its borders over which it only has limited control.

This means that no matter how effectively countries in the region engage in locust outbreak prevention, there will still remain a risk from migratory swarms, with significant outbreaks occurring around once every 10-15 years in the past.

This threat is likely to persist, due to a number of factors:

- The areas desert locusts can breed in neighbouring countries are commonly remote, rugged and difficult to reliably monitor with 100% accuracy[13]. For example the recent 2019-2020 locust outbreak across the region originated in Saudi Arabia's empty quarter in 2018 (see below), where despite significant past monitoring and suppression (Diagrams 2 and 3) locusts were able to breed largely unnoticed following a double cyclone and the resulting heavy rains.
- Climate change is raising the frequency and intensity of cyclones and heavy rain originating in the Indian Ocean. For example, in 2019 eight separate cyclones made landfall in Eastern Africa and Asia from the Indian ocean, an all time record, which was a strong contribution to the latest crisis. This means both means that conditions suitable for locust swarming are becoming more likely, as well as new regions becoming at risk of supporting locust breeding over time[14] [15].
- A number of areas in and around the Horn of Africa are insecure or have active conflicts, which makes the monitoring and suppression of locusts difficult to impossible over these areas for extended periods. This changes over time, but in the past has included Somalia, Yemen, Eritrea and parts of Ethiopia. Insecurity was also a key part of the recent locust outbreak, with ongoing conflict in Somalia and Yemen preventing monitoring until locusts had bred significantly and spread into Ethiopia, Djibouti and

[13] Showler, A.T. Desert locust control: The effectiveness of proactive interventions and the goal of outbreak prevention. Am. Entomol. 2018, 65, 180–191.
[14] Meynard, C.N.; Lecoq, M.; Chapuis, M.; Piou, C. On the Relative Role of Climate Change and Management in the Current Desert Locust Outbreak in East Africa. Glob. Chang. Biol. 2020, 26, 3753–3755.
[15] Salih, A.A.M.; Baraibar, M.; Mwangi, K.K.; Artan, G. Climate Change and Locust Outbreak in East Africa. Nat. Clim. Chang. 2020, 10, 584–585.

Kenya. While the extent of existing conflicts will change over time, it is likely that issues around insecurity in the region will persist in the coming decades.

As a result, it is likely that outbreaks migrating into the Horn of Africa will both continue, and the risks may potentially increase due to climate change and insecurity in neighbouring countries.

This has presented a serious challenge for the at risk countries in the region, as well as the FAO as part of its efforts to safeguard food security, due to the unpredictability and scale of these outbreaks and upsurges. The key issues experienced by efforts to respond are as follows[16]:

1. **Outbreaks are by their nature unpredictable, making early warning difficult and giving little time to respond.** While conditions suitable for locusts can be monitored, these do not always result in upsurges, and it is hard to maintain vigilance over the remote and insecure areas bordering the region from which migration can occur.
2. **Outbreaks are expensive to manage, stretching local budgets at short notice.** This currently means that donor funds must be rapidly mobilised before a significant response can begin, which must occur while locusts are still breeding exponentially and raising the final cost of intervention.
3. **Outbreaks are rare, making it hard to maintain personnel, equipment and institutional expertise in the region.** As a result, procurement of the additional resources needed must also occur at short notice, once locusts have been detected and funds are available for the response. This process can take a considerable amount of time (up to one year[17] in the case of operations in Central Africa in 2012-13). However, at the same time procurement must ensure that partners have the capacity to deliver, achieve value for money and the process must also be open and transparent, which fundamentally limits how fast it can occur.
4. **Other disruptions and crises can occur at the same time as the locust outbreak, diverting the attention of governments and donors and complicating responses.** In the last outbreak alone, as well as locusts governments and donors also had to deal with a changing security situation in the countries affected, the impact of COVID-19 and significant economic and political challenges which diverted attention and delayed responses across the region.

Recent outbreaks and upsurges

The following section details recent locust outbreaks and upsurges across Africa. Here we highlight in particular the dynamics of how swarms have formed recently, as well as the specific factors that have influenced the success of control operations in each case.

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[16]Showler, A.T.; Ould Babah Ebbe, M.A.; Lecoq, M.; Maeno, K.O. Early Intervention against Desert Locusts: Current Proactive Approach and the Prospect of Sustainable Outbreak Prevention. *Agronomy* 2021, *11*, 312. https://doi.org/10.3390/agronomy11020312
[17] MEETING ON THE DESERT LOCUST CONTROL FINANCING SYSTEM 11-13 March 2014, FAO Headquarters, Rome, Italy http://www.fao.org/ag/locusts/common/ecg/2164/en/Report_Meeting_Desert_Locust_Control_Financing_SystemE.pdf

The majority of these incidents impacted the Horn of Africa (the focus of our proposed financial product). However, we have also included a short overview of the 2003-2005 upsurge in West Africa. The incident was the largest upsurge in recent history across the continent (prior to the 2019-2020 upsurge) and has been extensively studied in the following years, meaning that it contains a number of useful lessons for control operations.

The 2003-2005 locust upsurge - West Africa

The 2003-2005 locust upsurge was the largest desert locust infestation in West and North Africa for more than 15 years. The upsurge began with four simultaneous uncontrolled outbreaks in Mauritania, Mali, Niger, and Sudan at the end of summer in 2003[18]. Additionally in October, unusually heavy rainfall from Dakar to the Atlas Mountains led to breeding conditions remaining favourable for over six months, enabling two consecutive generations of rapid breeding to take place.

Following the heavy rains, early warnings were launched by the FAO and the Desert Locust Information Service to alert countries and the donor community. Northwest African countries made considerable efforts to control locust infestations, but could not prevent the spring-bred swarms from invading the Sahel Region, from Cape Verde to Chad.

Despite awareness of the Locust swarm's movements towards the Sahel's breeding areas where countries are less capable of responding to locust infestations, the pace of donations was slow and the response resource constrained. Two more generations of breeding then took place during the summer of 2004, forming yet more swarms.

As a result, the estimated financial resources required to combat the outbreak increased from US$9 million in February 2004, which the FAO issued an initial appeal for but was unmet, to around US$100 million in early August[19].

The summer-bred swarms then invaded North-West Africa in October-November 2004, however poor ecological conditions prevented further breeding. Some swarms moved from Niger to southern Tunisia, and the Libyan coast. From here, they moved East to invade Egypt, Crete, Cyprus, and to a lesser extent, Israel, Lebanon, Jordan, Palestine and Syria.

The swarms finally reached winter breeding areas along the Red Sea Coast, where a further two generations of breeding took place between January and June 2005. Finally, a combination of unfavourable ecological conditions and control operations caused the upsurge to end in the Summer of 2005.

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[18] Desert Locust upsurge in 2004–2005 http://www.fao.org/ag/locusts/en/archives/1146/web04/index.html [Accessed on 02/09/2021]

[19] Pietro Ceccato, Keith Cressman, Alessandra Giannini & Sylwia Trzaska (2007) The desert locust upsurge in West Africa (2003 – 2005): Information on the desert locust early warning system and the prospects for seasonal climate forecasting, International Journal of Pest Management, 53:1, 7-13, DOI: 10.1080/09670870600968826

An FAO assessment[20] estimates the total cost of the campaign was around US$400 million, with US$280 million allocated for control operations and US$90 million for food assistance and rehabilitation of communities. This does not include the associated environment and nontarget costs, i.e, the damage pesticides had on the local environment. Overall 9.86 million ha were sprayed in North/North-West outbreak areas, while only 2.58 million ha were sprayed in the Sahel. This is indicative of the lower capacity of Sahelian West African Countries to respond to locust outbreaks relative to North/North-West African countries, as opposed to being representative of differing outbreak severities.

An estimated 8.4 million people in the Sahel region alone were negatively impacted by the Locust upsurge. Losses of expected cereal production reached 80%, 90%, and up to 100% in large areas of Burkina Faso, Mali and Mauritania respectively. Furthermore, legume crop losses were as high as 90% in affected areas of these three countries[21].

It is challenging to estimate the economic cost of locust infestations, but one assessment[22] estimated a 20% loss in crop production in the Sahel would be associated with a loss of around US$500 million. Additionally there were other associated crises such as mass migrations, resource-based conflicts among farmers, nomads and pastoralists[23].

What went wrong?

There were a number of factors identified in the sources above that contributed to failures in control operations during the upsurge:

- There was a lack of contingency funds ready to be used in the instance of the outbreak getting out of hand. The FAO does not have sufficient core funds to rapidly mobilize in times of an emergency, meaning they are overly reliant on rapidly scaling donations once a crisis is detected.
- Donors felt they were not adequately informed on the severity of locust infestations, and what the appropriate response was. This contributed to the bulk of funds arriving late, which allowed the outbreak to grow into an upsurge.
- The FAO Emergency Prevention System (EMPRES) was underfunded in Sahelian, Western, and Northern Africa before the outbreak.
- Many countries did not have sufficient locust monitoring and prevention capacity in place. This often degrades in locust recession periods, highlighting the importance of maintaining preparedness.

[20] Multilateral evaluation of the 2003-2005 desert locust control campaign, http://www.fao.org/3/bq986e/bq986e.pdf

[21] Allan T Showler, Desert Locust Control: The Effectiveness of Proactive Interventions and the Goal of Outbreak Prevention, *American Entomologist*, Volume 65, Issue 3, Fall 2019, Pages 180–191, https://doi.org/10.1093/ae/tmz020

[22] Yeneneh T. Belayneh "Acridid pest management in the developing world: a challenge to the rural population, a dilemma to the international community," Journal of Orthoptera Research, 14(2), 187-195, (1 December 2005)

[23] WDR 2005 - Chapter 3: Locusts in West Africa: early warning, late response https://www.ifrc.org/en/publications-and-reports/world-disasters-report/wdr2005/wdr-2005---chapter-3-locusts-in-west-africa-early-warning-late-response/

As a result of these failures, the FAO proposed a number of reforms, including the creation of a financial mechanism in order to pay for early operations in the next outbreak[24]. This is still outstanding, and is the aim of our proposed bond.

The 2007 locust outbreak - Yemen.

The 2007 outbreak arose following three days of heavy rains across March and May in the interior of Yemen between Thamud, Al Abr and the Oman border, reaching the edge of the Empty Quarter (Rub al' Khali). Conventionally this area is seen as a transit zone for locusts rather than an important breeding ground, however if good rains fall it can become a critical site in swarm formation.

Additionally, swarms from Saudi Arabia arrived in April near Thamud and laid eggs that hatched a few weeks later and formed hopper bands in May. The origin of this outbreak holds parallels with the 2019-2021 locust crisis, as the locust swarm's breeding area was in the Arabian Peninsula meaning in both cases sizable swarms that might impact the Horn of Africa could grow outside the East African countries' spraying operations. Analysis of survey results indicated this was the worst desert locust situation in Yemen for the past 15 years.

$2.4 million was allocated to the FAO by CERF to stop the outbreak before it significantly damaged agricultural production. The funding was used to procure key inputs such as twenty vehicle-mounted ULV sprayers, 50 backpack ULV sprayers, 50 ULV hand-held sprayers, alongside six survey and control consultants and other auxiliary equipment for tracking locusts. Additionally, 70,000 liters of chemical pesticide were airlifted to Yemen for Mauritania as a stockpile had remained from the 2003-2005 upsurge[25].

Therefore, unlike the 2019-2021 locust crisis, some locust control operations were able to take place in Yemen and control the spread of swarms before they could grow further. By August, 12,664 hectares of land had been sprayed (3,080 ha of which by air). However, hatching and breeding continued in the summer breeding areas, such as Wadi Hadhramaut, with swarms moving west to the central highland and the Eden coast.

Control operations had a significant impact on reducing desert locust populations, by the end of August only a few infestations remained in Wadi Hadhramaut. By the 23rd of September the Yemeni Government had declared most parts of the country locust-free and the spraying aircraft were subsequently demobilised. In total, 30,000 hectares had been sprayed using 30,000 litres of pesticides during August and September.

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[24] INSTITUTIONAL STUDY TO ENHANCE THE ROLES AND RESPONSIBILITIES OF THE DESERT LOCUST CONTROL COMMISSIONS ESTABLISHED UNDER ARTICLE XIV, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS COMMISSION FOR CONTROLLING THE DESERT LOCUST IN THE WESTERN REGION Available at: http://www.fao.org/ag/locusts/common/ecg/2148/en/Financial_Governance_Report_E.pdf

[25] ANNUAL REPORT OF THE HUMANITARIAN/RESIDENT COORDINATOR ON THE USE OF CERF GRANTS https://cerf.un.org/sites/default/files/resources/Yemen%202007%20%20FINAL%2010%20jANUARY%202009.pdf [Accessed 01/09/2021]

The 2013-2014 outbreak - Northern Somalia

On the 11-12 of November heavy rains (75-300mm) connected to Tropical Cyclone 03A fell on the coast, escarpment and plateau of Northern Somalia. Additionally, on the 11th the cyclone made landfall on the northeast coast of Somalia accompanied by rain of up to 30mm per hour. The heaviest rains fell in Puntland while some rain fell in Somaliland. This caused flooding and damage in some areas.

A few locust bands, carried by northerly winds to the west of the cyclone, arrived on the Northern Coast around the Las Khoreh area from southern Yemen. Some gregarious adults laid eggs in early December along the coast, and mature swarms began moving southwest.[26]

By January and February 2014 locust numbers had dramatically increased as a result of favourable breeding conditions associated with the heavy rains of the earlier tropical cyclone. Additional hatching and band formation continued on the northwest coast of Somalia, however by this point control operations had begun, with 76 ha of the surrounding area treated with green muscle (a fungus based pest control agent based upon Metarhizium that targets locusts and grasshoppers).

In March vegetation began to dry out, and an increasing number of swarms were moving inland as a result towards Boroma and Hargeisa, and into eastern Ethiopia. Ethiopia promptly initiated locust control operations.

By April, there was only one sighting of locusts (a gregarious band of hoppers), otherwise the locust swarms had all moved inland. Various small swarms, varying from 1-20km^2 in size, continued arriving into Eastern Ethiopia, and then moved inland. These swarms were beginning to mature and breed, a critical point in the locust situation as swarms can begin to exponentially increase in size. During April, control operations in Ethiopia had treated 2,370 ha in order to control this.

In May, reports continued to be made of immature swarms, small to medium-sized, on the plateau in Northwest Somalia, with some swarms moving along the plateau towards Las Anod. A dozen of these swarms were reported to move into eastern Ethiopia, and some of these swarms moved towards the Addis Ababa and Amhara regions. During April, control operations in Ethiopia had treated 2,372 ha, of which 2,150 ha was by air. This served to contain the spread of the locusts, and swarms died back from here.

The 2019-2021 locust upsurge.

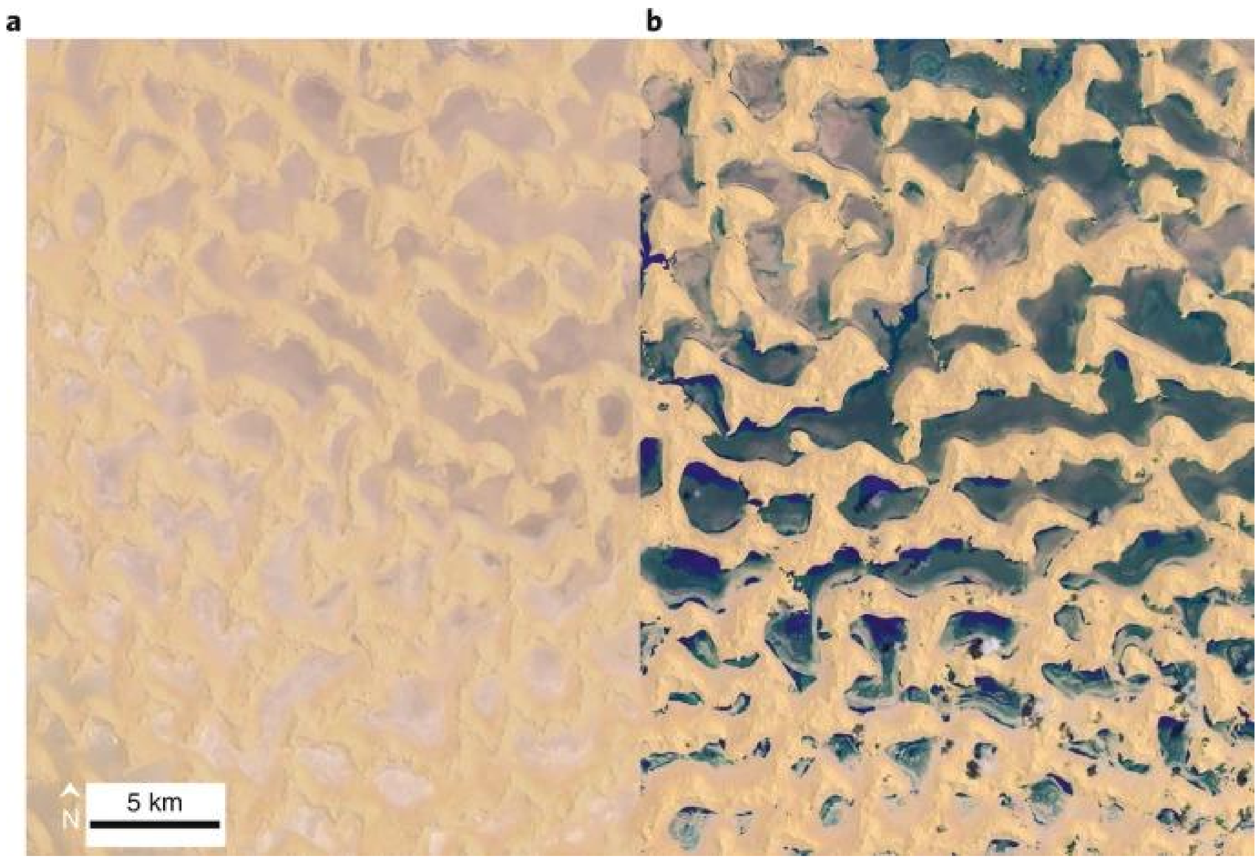
The most recent crisis (the tail end of which is still ongoing as of August 2021) has hit countries all the way from the Arabian Peninsula to the Horn of Africa and the Indian Subcontinent, and is the most severe locust upsurge in decades.

[26] Desert Locust outbreak in Northern Somalia (November 2013 - June 2014) http://www.fao.org/ag/locusts/en/archives/1032/2136/SOM2013/index.html [Accessed 01/09/2021]

The crisis originated back in 2018, when two cyclones caused very heavy rains across the "Empty Quarter" of Saudi Arabia and the mountains of Yemen (the first in May 2018 and the second in October). The impact of these unseasonable rains can be seen below in Figure 1, with the new plant life and wet soil leading to optimal locust breeding conditions.

As numbers rose, swarms began to form, whereupon they began to migrate into neighbouring Yemen, where conditions had also been wet. Locusts monitoring and control operations were impossible due to the harsh terrain combined with the ongoing insecurity, and the swarms continued to breed before finally making their way across the Persian Gulf and Red Sea in late 2019 to Iran and Somalia. Locust control was sparse in both countries, in part once again due to the ongoing conflict in Somalia, and swarms grew further as a result and moved into Pakistan/North West India as well as Ethiopia and Kenya.

Figure 1: Desert lakes in the 'Empty Quarter'.[27]



"Pools of water form in Rub' al-Khali desert, also known as the 'Empty Quarter', due to intense rainfall under tropical cyclone Mekunu. ***a****, Photograph taken on 13 May 2018 shows normal dry conditions.* ***b****, Photograph taken*

[27] Reproduced with permission, from: Salih, A.A.M., Baraibar, M., Mwangi, K.K. *et al.* Climate change and locust outbreak in East Africa. *Nat. Clim. Chang.* **10,** 584–585 (2020). https://doi.org/10.1038/s41558-020-0835-8

on 29 May 2018 shows the 'desert lakes' that facilitate locust breeding and survival. NASA Earth Observatory images by L. Dauphin using US Geological Survey data."

On the 17th of January 2020, the FAO activated its emergency response and started fundraising from key donors and launched the procurement process necessary to respond to the crisis[28]. Capacity to respond across Africa in particular was extremely limited at the start of the upsurge, and once contracted spraying aircraft had to be flown in from America and assembled. Spraying operations began in March 2020, and peaked over the end of Q2 and into Q3 of 2020.

The cost of the recent interventions

Estimates of the total cost of the 2019-2021 locust upsurge across the Horn of Africa vary depending upon which elements are included and over what region. However, from 2020 curbing the spread of locusts incurred significant costs associated with surveillance, and ground and air control measures.

Based upon reported FAO figures on their operations since March 2020, over 2.1 million ha over the Greater Horn of Africa region and Yemen has been treated with insecticides, saving an estimated US$1.3 billion in income related to tonnes of cereals and livestock output protected from locusts[29]. To achieve this, in 2020, US$185.4 million was committed across the Greater Horn of Africa and Yemen as part of the FAO appeal, with 2020 accounting for the majority of control operations. Meanwhile from January to June 2021 a further US$33.8 was committed to deal with the ongoing management of the remaining swarms, as well as ongoing income support for farmers affected.

Table 1 below shows the breakdown of control operation costs over the length of the appeal to date (up to June 2021, the most recent reported month). It displays the cost of both surveillance, spraying operations and the number of hectares sprayed. The equipment used for surveillance and control measures varied by country depending upon the situation on the ground, but were a combination of aircraft, vehicles, handheld and knapsack spraying equipment, vehicle-mounted spraying equipment, protective gear, and GPS devices which were deployed across the region.

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[28] Desert Locust Upsurge, Progress report on the response in the Greater Horn of Africa and Yemen, January–April 2021. Available from http://www.fao.org/3/cb4925en/cb4925en.pdf [Accessed 11.08.21]

[29] AO, n.d. FAO Locust Response Dashboard [online]. Available from: http://www.fao.org/locusts/response-overview-dashboard/en/. [Accessed 11.08.21]

Table 1: Costs and equipment from January 2020 to July 2021 in Ethiopia, Kenya and Somalia

	Ethiopia	Kenya	Somalia	TOTAL
Ground and Air Control Cost (USD$ millions)	$40.9	$15.1	$34.3	**$90.3**
Surveillance Cost (USD$ millions)	$7.2	$6.6	$7.1	**$20.9**
Treated Area (ha)	1,300,000	212,000	377,000	**1,889,000**
Deployed Fixed-Wing Aircraft	3	6	2	**11**
Helicopters	8	4	3	**15**
Vehicle: Pick Ups	50	21	23	**94**
Trucks	6	0	0	**6**
Motorcycles	110	0	0	**110**
Vehicle-Mounted Sprayers	48	20	40	**108**
Handheld/Knapsack Sprayers	8,796	943	108	**9,847**
Conventional Insecticides (litres)	951,000	357,000	90,000	**1,398,000**
Bio Insecticides (litres)	0	400	12,000	**12,400**
Protective Gear	6,500	833	300	**7,633**
GPS Devices	0	100	30	**130**
Human Health Test Kits	15	0	9	**24**

While costs were highest in Ethiopia, which experienced the greatest volume of locust swarms, unit costs of the intervention varied sharply. These are presented in Table 2, which looks at ground control costs on a per hectare treated basis.

We have also presented an estimate of the cost of chemicals, based upon deltamethrin, a common ULV (Ultra low volume) insecticide. The cost of deltamethrin is highly dependent on the quantity required, its availability[30], and its formulation. It is typically agreed on a per-tender basis and the cost has varied over time, however, the reported face value of the donated ULV formulation from Bayer in the most recent outbreak was $5.25/L. While other pesticides will vary in costs, this gives us an estimate of the cost of chemicals.

[30] Walker, K. (2000) "Cost-Comparison of DDT and Alternative Insecticides for Malaria Control," *Medical and Veterinary Entomology*, 14(4), pp. 345–354. doi: 10.1046/j.1365-2915.2000.00262.x

Based on the results below, the following conclusions can be drawn:

- The primary cost of interventions is the cost of the spraying equipment and personnel needed for operations, not the chemicals themselves.
- Costs were lowest per hectare in Ethiopia, and far more expensive in Kenya and Somalia.
- High per hectare costs in Kenya were primarily driven by the uncertainties early in the campaign, with a large number of aircraft contracted initially, at a significant upfront cost. These were then underutilised, with only 212,000 hectares treated in the end, compared to 1,300,000 in Ethiopia, raising costs on a per hectare basis. To avoid this in future operations, the FAO is moving towards a "pay per use" model, with contracts more based around the spraying operations needed, rather than a fixed upfront fee. This was adopted in May 2021[31].

Table 2: Per hectare from January 2020 to July 2021 in Ethiopia, Kenya and Somalia

	Ethiopia	Kenya	Somalia	TOTAL
Ground and Air Control cost per hectare	$31.5	$71.2	$91.0	**$47.8**
Litres deployed per hectare	0.7	1.7	0.2	**0.7**
Estimated cost of chemicals (at US$5.25/litre)	$3.8	$8.8	$1.3	**$3.9**
Estimated cost of spraying per hectare	$27.6	$62.4	$89.7	**$43.9**

Damage from recent outbreaks and upsurges

It is difficult to precisely estimate the full damage of locusts during an outbreak or upsurge, as this depends upon many complex factors. These include the monetary value of crops lost, the impact to subsistence agriculture and pasturage/rangelands for those already food insecure, the cost of food aid and the long term impacts on social and economic outcomes[32]. This becomes more complicated when estimating the damage averted due to control operations, as the full damage uncontrolled locusts could cause may be orders of magnitude higher if conditions suitable for their breeding persist.

However, the FAO has provided estimates of the damage averted by control operations during the most recent outbreak across the Horn of Africa (in their 2020-21 campaign). In this outbreak, the FAO estimates that around 4.3 million metric tonnes of cereals were protected, valued at around US$1.3 billion. On top of this, the

[31] Progress report on the response in the Greater Horn of Africa and Yemen, January–April 202, FAO http://www.fao.org/3/cb4925en/cb4925en.pdf

[32] Showler, A.T.; Ould Babah Ebbe, M.A.; Lecoq, M.; Maeno, K.O. Early Intervention against Desert Locusts: Current Proactive Approach and the Prospect of Sustainable Outbreak Prevention. *Agronomy* **2021**, *11*, 312. https://doi.org/10.3390/agronomy11020312

FAO estimates that around 830 million litres of milk were saved as a result of reductions to vegetation damage, and their support to pastoralists, which raises the total value of food saved to US$1.6 billion. Furthermore, the FAO spent US$65.85 million to safeguard livelihoods and support the recovery of farms damaged by locusts, which also included the purchase of feed to support pastoralists[33].

Given that the total cost of the intervention measures across the entire region was around US$141.5 million over the period, this suggests that active control operations result in very high damage reductions versus their cost, potentially over 10 times higher.

[33] Greater Horn of Africa and Yemen Desert locust crisis appeal, January 2020–December 2021, Revised appeal for sustaining control efforts and protecting livelihoods (six-month extension) http://www.fao.org/3/cb5468en/cb5468en.pdf [Accessed 01/09/2021]

Section 2: The Proposed Financial Product and Mechanism

In order to provide protection against future locust outbreaks, we propose the creation of a novel catastrophe product centered around the Horn of Africa. This would be established well in advance of the future outbreak, and would provide a fast initial response to target locusts once a migration is detected on a sufficient scale. This would allow a response to begin as soon as possible as the fundraising and procurement would have been carried out in advance of the outbreak, raising its effectiveness.

The FAO has discussed establishing a financial mechanism tied to escalating locust numbers previously to meet this challenge[34] however to date nothing has been created. It is our hope that establishing a bond/insurance to support a future response will meet the gap identified early in the response process.

The product would have the following broad features (these are explained in further detail as part of this section):

- The product would primarily cover Ethiopia, Kenya and Somalia (where possible). Potentially it could also include clauses to cover Tanzania, South Sudan and Uganda as well, as they are also exposed.
- The product could be issued either as a catastrophe bond or as an insurance product. There are arguments for each method and it is currently being determined which would be most advantageous (see the discussion later in this section for details).
    - If a bond, capital would be raised from interested investors via a bidding process, both from international capital markets or by companies looking to support effective control operations due to their current exposure to locusts. This would be in return for an annual coupon, paid for either by the countries in the region or by international donors.
    - If established as insurance, a contract would be formed with a reinsurer, who would put up the funds needed to support control operations in the event of a payout. This would be in return for an annual premium, paid for either by the countries in the region or by international donors.
- However, unlike traditional insurance, once triggered the product would pay out to the affected areas as control operations to suppress the outbreak rather than in cash, with the money used to fund these operations. These services would be procured as part of the product's launch, would cover the length of its issue and would be coordinated by the FAO in line with their guidelines.
- The total capital is expected to be in the range of US$20-40 million, with the exact total depending upon the cost of the procurement in the point above. This would be based upon four months of control operations across up to three chosen countries, most likely Ethiopia, Kenya and Somalia, to provide an effective response at the start of the locust outbreak.

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[34] INSTITUTIONAL STUDY TO ENHANCE THE ROLES AND RESPONSIBILITIES OF THE DESERT LOCUST CONTROL COMMISSIONS ESTABLISHED UNDER ARTICLE XIV, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS COMMISSION FOR CONTROLLING THE DESERT LOCUST IN THE WESTERN REGION Available at: http://www.fao.org/ag/locusts/common/ecg/2148/en/Financial_Governance_Report_E.pdf

- The product would have trigger conditions attached, tied to observing a sufficient population of locusts within the countries attached.
    - If one or more of the trigger conditions are met, funds are immediately paid to the contracted parties, and control operations would begin as soon as agreed in their conditions.
    - If the trigger conditions are not met over the life of the product (approximately five years) and there is no locust outbreak, the product would then be reissued, with another round of procurement. This would allow the premium/coupon and size of the payout attached to accurately reflect the updated risk situation on the ground and take advantage of any advances in technology since the previous procurement.
- If the early control operations funded by the payout are enough to stop the locusts, then no further action would be needed. If migrations continue and/or further control operations are needed past the period covered by the funds, it would instead provide enough time for a traditional fundraising and procurement campaign by the FAO to cover the additional costs needed, with no break in coverage.

As a result, this financial mechanism would solve a number of outstanding issues with the current response structure discussed above. It would allow a response to begin as soon as swarms are detected, rather than following rounds of fundraising and procurement, which could significantly reduce the damage early in the outbreak given the exponential growth possible in locust swarms. It would also provide a way to manage the risk of future outbreaks, based upon a regular coupon payment paid by member countries in partnership with donors, instead of sudden and very high intervention costs at short notice. In addition, it is likely that carrying out procurement in advance would allow a lower unit cost for the response.

As discussed above, it is very difficult to estimate the exact cost and damage reduction from an early intervention. However, given that existing control operations are estimated by the FAO to achieve a 10 fold return in terms of food losses averted, the benefits of early and effective action via improved financing are expected to be significant.

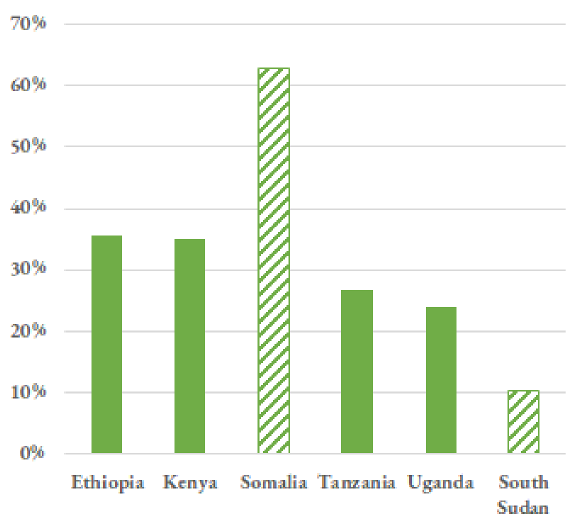
The choice of the Horn of Africa

The Horn of Africa was chosen as a location for this financial product as it combines a number of factors which mean it is highly exposed to outbreaks and could benefit from the risk reduction:

- The region is highly reliant upon agriculture, with agriculture, forestry and fishing accounting for between 25-35% of GDP in the case of Ethiopia, Kenya, Tanzania and Uganda, 10% in South Sudan, and over 60% of Somalia's GDP when figures were last available (Diagram 4).
- The majority of farmers in the region are small scale, increasing their exposure to crop losses and reducing their ability to manage risks alone.
- While government expenditure and capacity across the Horn of Africa is rising, the cost of a sudden intervention represents a significant cost which governments have struggled with in the past.

- Locusts require a regional response across the Horn of Africa to be effectively contained, which is supported by the structure of the mechanism.
- The region is exposed to sudden upsurges in locust numbers, and this risk is expected to rise over time due to climate change raising the probability of cyclones across the Indian Ocean.

Diagram 4: Agriculture, Forestry and Fishing, % of total GDP (2020, Somalia 1990, South Sudan 2015 (last available year))[35]



However, while the first product issued is proposed to cover the Horn of Africa there is no reason why other regions or countries would be unable to establish similar financial products to pool and reduce risk within their territories. Based upon their exposure potential countries or regions interested in this could include West Africa (where the FAO has also identified a need for a financing mechanism to be in place targeting locusts[36]), Sudan, Egypt, the Arabian peninsula, Pakistan and India.

Based on the most recent locust upsurge, the majority of control operations in future outbreaks are expected to occur in Kenya, Somalia and Ethiopia, which are on the frontline of migrations.

However, it is possible for migrating locusts to originate from other regions than the Arabian peninsula, and as a result the product could also cover Tanzania, Uganda and possibly South Sudan for this reason.

Somalia has been included in the proposal, as it lacks the capacity to respond itself, farmers there are highly exposed to locust outbreaks, and effective control in Ethiopia and Kenya is difficult if swarms can breed across the border in Somalia unimpeded. However, while aircraft spraying in Somalia can be based in Kenya and Ethiopia, conflict across Somalia may impede control operations, which must be agreed with the contracted parties. The inclusion of Somalia may also complicate the product's establishment due to international capital controls, and this is being investigated.

As a result, while we envision operations in Somalia will be included in the proposal, the product could also function without Somalia's inclusion. Under that scenario, operations there instead would operate using existing resources, and any expansions would be funded at a later date under the standard FAO response process when it becomes possible.

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[35] World Bank figures, https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS accessed 09/08/2021

[36] INSTITUTIONAL STUDY TO ENHANCE THE ROLES AND RESPONSIBILITIES OF THE DESERT LOCUST CONTROL COMMISSIONS ESTABLISHED UNDER ARTICLE XIV, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS COMMISSION FOR CONTROLLING THE DESERT LOCUST IN THE WESTERN REGION. Available at: http://www.fao.org/ag/locusts/common/ecg/2148/en/Financial_Governance_Report_E.pdf [Accessed 11/08/2021]

Sudan has been excluded from the proposed product launch, as FAO locust control operations there are small compared to Ethiopia, Kenya and Somalia. International capital restrictions around Sudan also would severely complicate including it.

How the financial mechanism would function

The choice of a bond versus an insurance product

There are a number of ways the financial product could be structured. Primarily this would either be as a bond, or as an insurance product.

Both have potential reasons why they may be suitable as a financing structure, and may have implications for the premiums/coupon of the product and how complex its launch will be. However, the broad functioning of the product would not change depending on the financing structure chosen, both in terms of the intervention measures attached, their cost once triggers are met, as well as the triggers attached to the product.

Factors in support of structuring the product as a bond include:

- A bond allows multiple multiple sources of finance to be combined to support the payout. This may be an advantage if concessional capital is available to cover part but not all of the payout.
- A bond may allow resilience rebates to be more easily captured, via lower coupon payments upon reissue, in the event of improvements to preparedness in the region.
- Albeit unlikely, reinsurer default likelihood would not be a factor that would be taken into account for a bond structure
- If the product were to be increased in scale upon reissue, money may be easier to secure on capital than reinsurance markets
- There may be the potential to tap into recently announced concessional climate adaptation finance via capital markets

Factors in support of structuring the product as an insurance contract include:

- Some insurers are more willing to take a chance on a novel product requiring novel risk modelling compared to traditional investors.
- The set up cost of issuance is lower for an insurance product than for a catastrophe bond
- If the size of the payout is within the ability of a single insurance partner to meet without liquidity issues, or exposure to the disaster in the rest of their portfolio of commitments, insurance can be lower cost compared to a bond. This is because capital does not need to be tied up in a low yielding special purpose vehicle with insurance. Given that many firms would not have significant exposure to

agriculture in East Africa and the size of the payout is expected to be around US$20-40 million this may be the case with the proposed locust product.

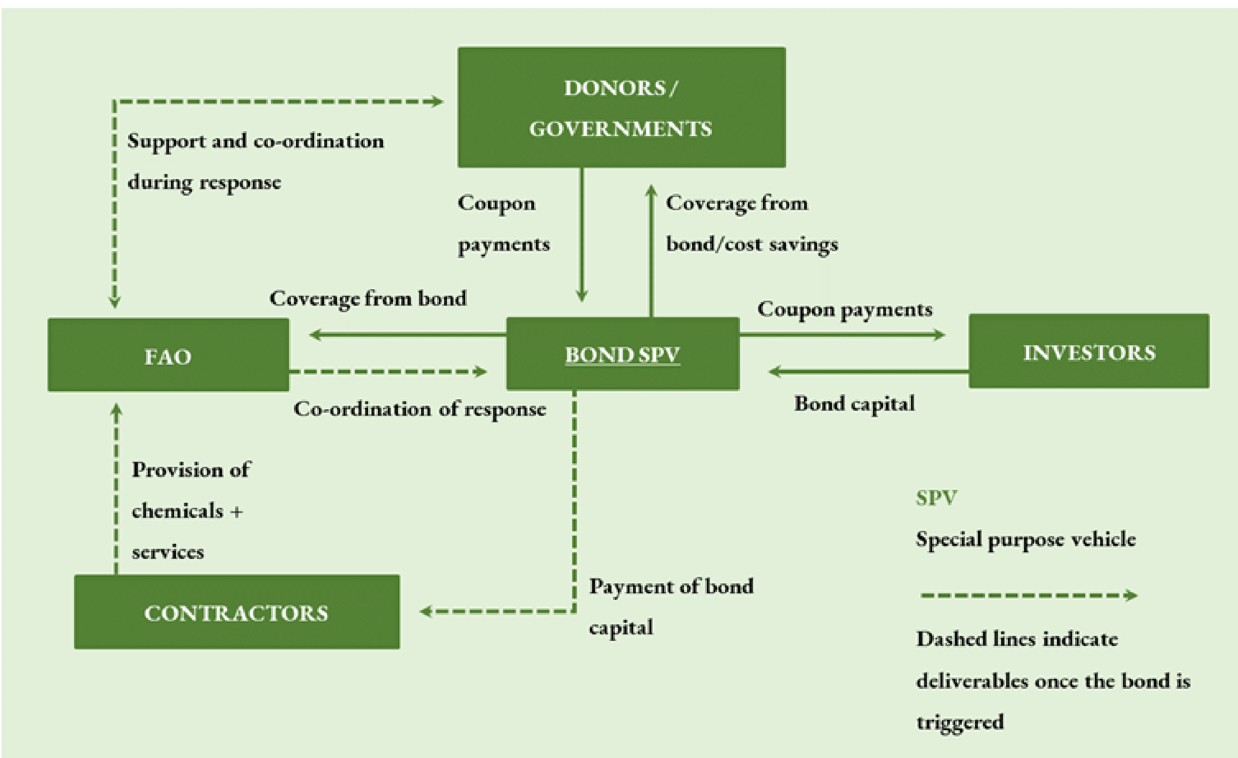
- Insurers may be more flexible with the trigger design of the product, e.g. openness to using satellite data to determine swam density as a trigger

The structure of the bond/insurance contract

The following describes the product's structure, if issued as a bond.

In order to function, the bond would need support from a number of stakeholders. These have been summarised below in Figure 2, which also details what would be needed from each party and the benefits they would receive from the bond (which we discuss later in this section in more detail).

Figure 2: Bond stakeholders and deliverables



Bond SPV

Upon launch, a Special Purpose Vehicle (or SPV) would be created by the key actors to hold the bond, and service level agreements for control operations would be created both for the suppliers and for contractors necessary for the provision of successful control operations. This SPV would hold the bond capital provided by investors in escrow, until the funds are needed, with the capital held in a liquid and risk free security such as US treasury bonds.

Investors

Investors would provide the bond capital, in exchange for coupon payments, which we discuss later in this section. Potential investors in the bond include MDBs such as the World Bank and African Development Bank, aid agencies, and private investors to take on senior debt.

Meanwhile, if issued as an insurance contract, the product would function in a similar way, other than the Investors and the Bond SPV being replaced by an insurer/reinsurer:

Insurer/reinsurer

Insurers would commit to provide the payout needed in the event of a future locust outbreak, in exchange for premium payments, which we discuss later in this section. Potential parties here would likely in reality be reinsurance companies, as they are able to take on contracts of this size and accurately model novel risks.

Beyond the funds needed, there are a number of other parties attached to the product. These are as follows:

Donor organizations

Donor organisations would commit to pay the majority of the bond's coupon payments, necessary to secure the capital. In return, donors would receive the coverage from the bond. This would both manage their risk from a future outbreak by moving costs onto a flat coupon rather than a sudden large liability from the next outbreak, as well as reducing the total cost of the next intervention via faster and more effective action.

Local governments

Local governments would also have a part to play in the bond, and their support would be vital for it to function. Firstly, local governments would coordinate with the FAO much as with recent control operations in the current campaign, sharing information and providing staff on the ground to help with the response. In addition, their help would be needed in securing the facilities, chemical licenses and import paperwork needed for the contractors to operate. This would need to be carried out in advance so that work can begin as soon as possible. Local governments also formed a vital link in the chain bridging between the FAO and farmers in past outbreaks, who are a vital part of locust surveillance on the ground.

Finally, while local governments have constraints upon their funding, they may provide part of the coupon payments with support of the donor organisations.

FAO

Much as with current operations, the FAO would have a key role to play in the proposed bond, with the organisation monitoring locust numbers, managing the response once the trigger is met and co-ordinating with donors and local governments. This would be in line with the current skills, capacities and responsibilities of the FAO in outbreaks, the bond would simply provide them with the resources they would need for the next outbreak. As part of this, the FAO would also be a key partner in determining procurement needs from the contractors.

Contractors

Contactors would be the parties supplying goods and services to the bond once it is triggered, for example providing chemicals, surveillance or control operations. These would be procured upon the bond's launch, and once the bond is triggered during the next outbreak, funds would immediately be paid to the contractors from the SPV, and work could begin at the FAO's direction in partnership with local authorities. Further detail on the goods and services needed, and their estimated total cost, are provided below.

Others

On top of the direct parties to the bond, there would be a wide range of additional beneficiaries. These would include civil society, through potentially lower food prices, as well as smallholder farmers due to lesser economic impact in the event of future outbreaks. Investors in African food systems may also benefit from the increased resilience, which could range from large plantations to small scale logistics and processing operations.

The trigger

A key part of the product is the trigger, which are the conditions for the payout to be activated and control operations to begin. These would be specified at the product's launch, and would be tied to detecting a significant volume of swarming locusts within the countries attached.

This would be set to well above the threshold of regular monitoring and control operations (which average up to around 6,000 hectares annually across the region (Diagram 1 above)) and would be expected to pay out on a magnitude of around once every 10 to 15 years (the frequency of severe locust outbreaks in the Horn of Africa over the last few decades).

Surveillance and monitoring would be based upon the existing infrastructure established over the region to monitor locust populations during recession periods. These include satellite observations of vegetation in locust breeding zones, combined with direct on foot or aerial observation of the areas in question.

The exact triggers are in the process of being determined in consultation with the parties in question, but some potential conditions are included below, with at least one being met triggering the response:

1. Locust populations observed within the coverage area demonstrating swarming behaviour over two standard deviations above regular recorded populations. This would be the primary trigger.
2. Recorded crop losses from locusts within the coverage area above a value of half a million dollars or damage recorded from locusts to 2,000 hectares of farmland. This would be a secondary trigger, in the event that locusts are causing damage to farmers at a point where the survey teams are unable to accurately measure populations in order to trigger point one above.
3. The ongoing recorded migration of locust swarms into the territory covered, from a neighbouring area experiencing an upsurge in locusts. This would cover a scenario where locusts had not yet arrived in numbers sufficient to meet point one, but where further migrations and locust population growth is close to guaranteed given conditions on the ground.

As part of these triggers, it is also likely that mechanisms for triggering an early response could be included via a "proof of loss" clause. This would involve an early payout at the discretion of the FAO, even when triggers are not yet met, under circumstances where it is clear that the triggers would be met shortly afterwards. If one or more of the triggers are met over the coming months as expected, the response would continue as planned, while if the triggers are not met the FAO would pay back the capital to the investors/insurer.

Finally, there would also be the option to not trigger the payout based upon the judgement of the FAO, even if the trigger conditions are met. Managing locusts by the FAO is a difficult balance, and escalating alert levels and responses is a balance between the probability of damage and the risk of a false alarm and damaging credibility[37].

Unlike regular catastrophe insurance, the proposed locust payout would be in the contracted chemicals, equipment and operations rather than a monetary payment. While it is unlikely that such an intervention would not be needed if locusts are present in numbers above the trigger, it is possible that conditions on the ground suggest that the outbreak will be short lived or there are other factors that mean that the response will not be necessary. In this case, the FAO could postpone the product's activation, either triggering it at a later date once the situation is clearer or not at all, if the threat passes.

Intervention measures:

Once the trigger conditions are both met and approved by the FAO, the payout of funds would begin and the contracted parties would provide support in line with their agreements, established at the product's issuance. While these will vary depending upon the capacity already present and the technology available at the time of issue, the services contracted will be expected to fall along the following lines:

[37] INSTITUTIONAL STUDY TO ENHANCE THE ROLES AND RESPONSIBILITIES OF THE DESERT LOCUST CONTROL COMMISSIONS ESTABLISHED UNDER ARTICLE XIV, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS COMMISSION FOR CONTROLLING THE DESERT LOCUST IN THE WESTERN REGION. Available at: http://www.fao.org/ag/locusts/common/ecg/2148/en/Financial_Governance_Report_E.pdf [Accessed 11/08/2021]

Surveillance assets

A key part of responding to locust swarms is effective surveillance. Locusts migrate rapidly, travelling up to 130 km daily, and swarms can change course and divide at short notice. As a result, control operations rely on surveillance, which works to locate swarms.

Surveillance is likely to be a combination of air assets, typically light aircraft, helicopters, and ground assets, typically small pickup trucks or other all terrain trucks. These can be equipped with spraying equipment in some cases, however their primary job is to locate and follow swarms, based upon their likely locations or local reports. This is both to allow accurate as well as safe spraying, and in some circumstances locusts are tracked for extended periods while in close proximity to human habitation before they can be safely sprayed to minimise exposure to chemicals.

While local personnel can provide part of the surveillance teams, accurately monitoring locusts requires training and equipment at a level which is often not available during recession periods. Total spending across Kenya, Ethiopia and Somalia on surveillance so far in the 2020-21 outbreak totalled around US$20.9 million (Table 1 above). As a result it is likely that the payout would also have to include funding for additional surveillance assets and personnel to be deployed.

Purchase of insecticides

As part of control operations, suitable insecticides would need to be rapidly imported in sufficient quantities to meet spraying requirements.

Insecticides utilized for locust control should meet FAO specified treatment guidelines, in summary: have quick knock down, favourable dose rate and acceptable environmental impact profiles. Ultra Low Volume (ULV) formulations are recommended due to various practical and economic advantages relevant to desert locusts. For example ULV deltamethrin formulas demonstrate a widely utilized desert locust insecticide formulation with desirable characteristics, however others could be used. Products would be procured based upon FAO recommendations, cost competitiveness and licensing requirements in the countries where the control operations would occur. Importantly, with this occurring in advance of the outbreak there would be sufficient time to ensure cost and product effectiveness.

The FAOs Pesticide Research Group (PRG) recommends ULV treatment protocols as follow:

The PRG continues to recommend ULV application as the standard technique to cope with the logistics of treating large areas with populations of locusts or grasshoppers, especially as these generally occur in remote areas without water. The application of about one litre per hectare is preferred to ensure that sufficient droplets are applied for adequate coverage. However, depending on what formulation is available and when calibration is accurate and vegetation is not too dense, a lower rate of down to 0.5 litres per hectare is acceptable if aerially applied over large areas. Such low volumes necessitate a *narrow droplet spectrum to reduce waste of insecticide in large droplets, and a range of 50-100 µm VMD (Volume Median Diameter) droplet spectrum using rotary atomisers is advocated. On the other hand, higher volume application rates (2 litres per hectare) may be more effective in very dense vegetation, e.g. as often encountered in Red Locust habitats.*

ULV suitable pesticides are listed in Table 3 below, adapted from existing FAO insecticide field trials (http://www.fao.org/3/bu337e/bu337e.pdf).

On a national level, tenders for insecticide are typically made directly to the FAO by government representatives in the relevant African countries[38]. In instances where governments are slow to respond, individual farmers may seek to purchase insecticides of their own accord. However, this is problematic as farmers are at risk of purchasing counterfeit products and are often unequipped with the basic PPE that is necessary for the safe handling and usage of these chemicals[39].

New FAO policies that focus on the redistribution of excess insecticide stock from within the Middle East and Africa aim to reduce waste of insecticide stock whilst increasing access to these chemicals, as in the past effective short-term response has been hindered by slow insecticide delivery.

Table 3: Potential insecticides for inclusion as part of the payout.

Insecticide	Class	Physical properties		Direct treatment dose rate (g a.i./ha)		Speed of action at verified dose rate (hours)	Primary mode of action
		Density (ULV formulation)	Viscosity (ULV formulation)	Hoppers	Adults		
Bendiocarb	Carbamate	n/a	n/a	100	100	1-2	AChE inhibition
Deltamethrin	Pyrethroid	0.5	n/a	12.5 - 17.5	12.5 - 17.5	1 - 2	Na channel blocking
Lambda-cyahlothrin	Pyrethroid	1.3	n/a	20	20	1 -2	Na channel blocking
Fenithrothin	Organophosphate	n/a	n/a	400	400	3 - 48	AChE inhibition
Metarhizium anisopliae	Fungus	n/a	n/a	50	50	> 48	Mycosis

[38] FAO. (2015) *Stakeholder Workshop on the Procurement and Supply of Pesticides for Locust Control* [online]. Available from: http://www.fao.org/ag/locusts/common/ecg/2257/en/Procurement_meeting_2015_Report_E.pdf [Accessed 16.04.21]

[39] EU Policy Department. (2021) *The Use of Pesticides in Developing Countries and Their Impact on Health and the Right to Food* [online]. Available from: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/653622/EXPO_STU(2021)653622_EN.pdf [Accessed 16.04.21]

Due to difficulties obtaining accurate quotes for a wide range of insecticides that could be used for locust control, all cost-related investigation has been focused on deltamethrin. Deltamethrin was chosen for its fast-acting effects coupled with low mammalian toxicity and extensive history of use in the fight against locust plagues[40 41 42].

The cost of deltamethrin is highly dependent on the quantity required, its availability[43], and its formulation. It is typically agreed on a per-tender basis and the cost has varied over time. However, ULV formulation from Bayer was given a face value of 4.4 euros per litre[44] (approximately US$5.25/litre) in the most recent intervention, which we have taken as an indicative price.

The insecticides recommended for further study (fenitrothion, malathion, deltamethrin and Metarhizium acridum) are appropriate for use in ULV formulations [45 46 47] as is typical for all insecticides designed for use against migratory insects[48]. The overall efficacy of ULV formulations is highly dependent on the droplet size produced by spraying equipment and other factors, such as wind driven dispersion and settling time, which combine to affect the evenness of coverage[49]. Given the limited amount of locust-specific research regarding appropriate droplet sizes for ULV use and the highly variable atmospheric conditions experienced during the locust response operations, the FAO has recommended that all activities involving the ULV application of these compounds should begin experimentation with focus on the 50–100 micron range[50].

It may also be possible to partner with relevant agrochemical companies to ensure required insecticide(s) can be rapidly scaled upon the triggering of the payout. A desirable partnership would involve a rapid formulation and

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[40] Natalie M Bowman *et al.* (2018) "Pyrethroid Insecticides Maintain Repellent Effect on Knock-Down Resistant Populations of Aedes Aegypti Mosquitoes," *PLoS ONE*, 13(5). doi: 10.1371/journal.pone.0196410.

[41] Brown H.D., Kieser M.E. (1997) Locust control with deltamethrin. In: New Strategies in Locust Control. Birkhäuser Basel. https://doi.org/10.1007/978-3-0348-9202-5_37

[42] MacCuaig, R. D. *et al.* (1979) "Pesticides for Locust Control," *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, 287(1022), pp. 447–455. doi: 10.1098/rstb.1979.0075.

[43] Walker, K. (2000) "Cost-Comparison of DDT and Alternative Insecticides for Malaria Control," *Medical and Veterinary Entomology*, 14(4), pp. 345–354. doi: 10.1046/j.1365-2915.2000.00262.x

[44]

https://www.media.bayer.com/baynews/baynews.nsf/id/Bayer-stands-by-Kenya-and-Uganda-in-fight-against-desert-locust-devastation?Open&parent=news-overview-category-search-en&ccm=020

[45] Britch, S. C. *et al.* (2010) *Evaluation of ulv and thermal fog mosquito control applications in temperate and desert environments*. Ft. Belvoir: Defence Technical Information Center. Available at: INSERT-MISSING-URL [Accessed: 15.04.2021].

[46] Al-Sarar, A. S. *et al.* (2011) "Effects of Space Spray Application Methods on Fenitrothion Efficacy and Development of Resistance in Culex Pipiens," *Journal of the American Mosquito Control Association*, 27(2), pp. 129–134. doi: 10.2987/10-6055.1

[47] Kassa, A. *et al.* (2004) "Laboratory and Field Evaluation of Different Formulations of *metarhizium Anisopliae* Var. *acridum* Submerged Spores and Aerial Conidia for the Control of Locusts and Grasshoppers," *BioControl*, 49(1), pp. 63–81. doi: 10.1023/B:BICO.0000009384.46858.aa.

[48] Wei K *et al.* (2020) "Preparation of a Chlorantraniliprole-Thiamethoxam Ultra Low-Volume Spray and Application in the Control of Spodoptera Frugiperda," *ACS omega*, 5(30), pp. 19293–19303. doi: 10.1021/acsomega.0c02912.

[49] Farajollahi A *et al.* (2012) "Effectiveness of Ultra-Low Volume Nighttime Applications of an Adulticide against Diurnal Aedes Albopictus, a Critical Vector of Dengue and Chikungunya Viruses," *PloS one*, 7(11), p. 49181. doi: 10.1371/journal.pone.0049181.

[50] Pesticide Referee Group (FAO). (2014). Evaluation of Field Trials Data on the Efficacy and Selectivity of Insecticides on Locusts and Grasshoppers [online]. FAO. *Available from: http://www.fao.org/3/bu337e/bu337e.pdf* [Accessed: 13.04.21]

supply pipeline enabling control operations to be immediately initiated (utilizing existing stockpiles of insecticides) and maintained (with rapidly formulated insecticide) upon trigger conditions being met.

Spraying equipment and control vehicles

Suitable spraying equipment is critical to effective control, especially when utilizing ULV formulations. Sprayers must be able to produce a droplet spectrum with suitable: Volume Median Diameter (VMD), optimally between 50 and 10 um; and Number Median Diameter (NMD) optimally less than half VMD yielding a VMD:NMD ratio of greater than 2. Target droplet spectrum should be maintainable at a suitable flow rate for the sprayer. Rotary sprayer atomizers are best suited to achieve consistent VMD, though must be vehicle mounted.

Mounting of sprayers on suitable vehicles, pickup trucks or aircraft, define treatment and cost characteristics. Agreements to obtain required numbers of vehicles and aircraft for the anticipated response should be predetermined according to existing knowledge from control operations, such that vehicles can be rapidly made available upon triggering of the payout.

Finally, while local staff can support ground operations, it is likely that skilled pilots with past experience will have to be contracted for the aerial spraying. This is a significant cost in the current intervention, and pilots, their aircraft and support staff are likely to be a large cost item in the payout as a result, unless other forms of intervention (such as drones) could be deployed and trusted to perform the same tasks.

Steps once the intervention is completed

Following the trigger and response is completed, the effectiveness of the interventions would be assessed. This would allow any lessons learned to be incorporated, if needed, and the product would be reissued. The reissuance process would vary slightly, depending upon the structure of the financial mechanism:

- If established as a bond, a new bond would be created. This would involve a fresh round of procurement and new capital would be raised.
- If established as an insurance product, procurement would once again be rearranged for the next round of interventions required, and the donors/governments attached would once again begin paying premiums in return for further coverage.

In both cases it is possible that the cost of the bond coupon/insurance premiums would change upon its reissue.

Projected costs

While the total capital will be determined by the bids submitted by contractors and agrochemical suppliers as part of the procurement process, it is possible to estimate the expected range of costs, based upon the recent 2020-2021 campaign.

The cost of surveillance was estimated based upon the 2020 surveillance cost, scaled from a full year to four months. However, this may be higher or lower at the time of tender, depending upon the fixed costs associated with deploying the surveillance assets, and the extent of local equipment available. We are trying to determine these costs in greater detail currently; however, at the moment, we have applied a +/-10% factor on the total regional costs to model high and low scenarios.

The payout aims to provide four months of control operations, across the three core countries of Kenya, Ethiopia and Somalia. In the initial four months of operations taking place in the previous campaign just over 460,000 hectares were sprayed across the four countries (March to June for Kenya and Ethiopia, May to August for Somalia, where control operations were delayed), and this forms our lower bound estimate.

However, to ensure sufficient coverage the procurement process may wish to contract an additional margin, to ensure a sufficient area can be treated if locust intensity in the early period is higher than expected. With this in mind our low scenario looks at a 460,000 contracted hectare treatment, while our mid and high scenarios add a 20% margin to area to bring the total to ~550,000 hectares.

This would be contracted based upon a maximum total area sprayed per month (up to 150,000 ha for example) based upon need up to the total contracted, to be deployed within a set period, for example six months. This would allow the pace of the control operation to rise and fall based upon need, and the response either to cover a four month intensive spraying period before additional resources could be deployed, or a longer period of lower intensity if the swarms subside. In addition, there would ideally be a clause included for the unit cost of spraying above the initial contracted volume if further operations are needed, to allow a seamless transition to longer term control operations.

Unit spraying costs were estimated based upon a number of benchmarks, taken from Table 2 above:

- The low scenario takes the cost of control operations in Ethiopia, where economies of scale were high and assets well utilised. Chemical usage also takes Ethiopia as a benchmark.
- The mid scenario takes the average cost per hectare for the region over the 2020-21 campaign.
- The high scenario takes the cost of control operations in Kenya, where utilization was low and unit costs high as a result. This is a pessimistic scenario, but it is possible that spraying companies with high fixed costs would be forced to submit high bids for the initial 550,000 hectares to cover these costs, and

lower follow up costs. However, we do not believe costs will be this high.

Table 4: Projected costs of the payout, based upon the recent intervention

	Low	**Mid**	**High**
Hectares treated	460,000	550,000	550,000
Estimated chemical use (litres per hectare)	*0.7*	*0.7*	*1.7*
Estimated cost of spraying per hectare	*$27.6*	*$43.9*	*$62.4*
Estimated cost of surveillance (US$ million)	$6.3	$7.0	$7.7
Estimated cost of chemicals (US$ million)	$1.8	$2.1	$4.9
Estimated cost of spraying (US$ million)	$12.7	$24.2	$34.3
TOTAL COST (US$ million)	**$20.8**	**$33.3**	**$46.8**

Overall, these assumptions give us a range of costs, most likely between US$20-33 million, but possibly as high as US$47 million. While the total funding required will not be known until the procurement negotiations occur, the following points can be made:

- The countries and donors are already exposed to the costs of containing locusts above, with or without the proposed product. Due to the nature of the locust threat, future locust outbreaks and upsurges have a high probability of occurring in the coming decades, and emergency funding and procurement will need to be raised when they do.
- Securing a response upfront is likely to allow better long term planning by the contractors and suppliers involved, allowing both a faster response and a lower unit cost compared to procurement at short notice while an outbreak is underway.
- While costs may vary depending upon a number of factors, securing the contract would not only grant the companies the initial payout when they are needed, but also the significant potential of additional follow up work in the event that the outbreak goes on longer than the initial response. This would likely lower the cost of the procurement, and makes a contracted rate in line with the cost of the Kenyan response unlikely (our high scenario).

Expected bond coupon/insurance premium

Once the total funding required has been established, this will need to be secured.

For a bond this will be raised from international capital markets much in the way that other forms of sovereign and corporate debt are issued, with investors providing the capital needed in exchange for an annual coupon at an auction. Investors purchase catastrophe bonds for a number of reasons, however one of the key motivations is that catastrophes typically have high diversification compared to the market as a whole.

Meanwhile for insurance, an insurer/reinsurer will offer a payout for an agreed premium, which would be subject to negotiation depending on the expected frequency of locust outbreaks, and measures taken to contain this.

While the coupon/premium investors/insurers are willing to accept will vary, they will depend upon a few core factors:

- The risk free rate of borrowing (the return the investor could have achieved at zero exposure). For this we have taken current US treasury rates on a 10 year bond (approximately 1.35% nominal at time of writing).
- The expected frequency of a locust outbreak meeting the trigger criteria. Based upon recent outbreaks and upsurges, this would range from between a one in ten to a one in fifteen event (a further 6.7-10% on top of the risk free rate).
- The investor premium, which is the premium investors require above the factors above to provide funding. This varies upon a number of factors, but will be lower if the payout is based on a clear and transparent trigger and how accurately the investor can model the expected frequency of outbreaks from past data. Investor premiums therefore vary from product to product, however they typically vary from around 0-3%, but can be as high as 8%, depending upon the age of the product and how much it is trusted. Given that the product is new, we have therefore taken a range of premiums into account, from 1% to 4%. However, these will hopefully move towards the lower end of the range over time as the product builds trust with investors and insurers.

Table 5: Projected coupon rates, low, middle and high

	Low	Mid	High
Risk free rate:	*1.35%*	*1.35%*	*1.35%*
Expected payout frequency	*6.7%*	*8.0%*	*10.0%*
Investor premium	*1%*	*2%*	*4%*
Total coupon rate	**9.0%**	**11.4%**	**15.4%**

Taking these potential coupon rates and applying them to the total payout range (calculated in Table 4), we can now calculate a range of potential annual coupons/premiums for the payout. These are summarized below in Table 6, which shows an expected range of around US$1.9-3.8 million annually based on mid/low scenarios. This could rise up to US$7.2 million in a worst case high scenario.

Table 6: Projected annual coupon/premium payments, low, middle and high coupon/capital scenarios (US$ million)

		Product capital		
		Low	**Mid**	**High**
Coupon/	**Low**	$1.88	$3.00	$4.22
Premium	**Mid**	$2.36	$3.77	$5.32
	High	$3.19	$5.11	$7.19

Potential synergies and resilience rebates

The structure laid out above is based upon the available technologies, capacities and methods used in the recent 2020-21 locust control efforts across the Horn of Africa. This had a high degree of effectiveness, and took advantage of advances in surveillance and spraying technologies since past outbreaks, but it still contains limitations. In particular, it assumes that in a future disaster capacity will again have to be contracted and brought in for both surveillance and control efforts, as with past outbreaks.

However, it also may be possible to build capacity in the region beforehand through other investments and actions, meaning fewer additional resources would have to be contracted. This would in turn reduce the payout required when it is reissued and the coupon/premium needed to maintain it, capturing a resilience rebate.

There are a number of interventions in this category that could support the product on top of their own benefits:

- The expansion of fixed and rotary wing drones has been proposed across Africa already[51]. These could have a number of benefits for survey teams looking to monitor locusts during recession periods, and this alone may well justify their deployment. However they could also help significantly during the initial monitoring of swarms, allowing an earlier and more accurate triggering of the payout. Drone deployments would also reduce the need to contract helicopters and other additional surveillance assets once swarms are detected, lowering the payout necessary.
- Furthermore, drone deployments could also support spraying operations, depending upon the types of platforms deployed and the locations of the swarms. This could reduce the requirement to contract additional spraying assets as part of the response.
- Finally, effective actions in the regions neighbouring the Horn of Africa could also provide a resilience rebate, by reducing the probability of future outbreaks and therefore the coupon/premium. However, this is difficult for the reasons discussed above, including ongoing conflict, climate change and the remote nature of breeding zones.

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[51] AUDA-NEPAD, (2018) *Drones on the Horizon – transforming Africa's agriculture* [online]. Available from: https://www.nepad.org/publication/drones-horizon-transforming-africas-agriculture [Accessed 11.08.21]