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LIMITED PREPAREDNESS: CHALLENGES DURING DESERT LOCUST MANAGEMENT IN KENYA

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ABSTRACT

Desert locust invasions could lead to serious food insecurity. However, effective and efficient management of the pest is usually faced with a myriad of constraints. This study sought to determine the challenges that Kenya faced during the 2019-2021 Desert locust management operations. The study used a mixed methods approach using ex-post facto evaluation and cross-sectional survey designs. The target population included Desert locust affected persons. Multi-stage stratified and purposive sampling were used to target a sample size of 900 respondents drawn from 30 counties that were affected by Desert locusts. Structured questionnaire and focus group discussion (FGD) were used to collect quantitative and qualitative data that was analysed through descriptive and inferential statistics as well as thematic review. The findings revealed that human resource and geographical challenges had 17% and 16% hindrance to Desert locust management, respectively. Technical and coordination challenges contributed 15% obstruction each; while financial limitations had 13% impediment. Political and sociocultural challenges contributed 12% hinderance each. The concludes that challenges during Desert locust management exacerbated human security risks from Desert locusts. The study recommends continuous capacity development through regular maintenance of equipment, continuous training of personnel and periodic update of preparedness plans.

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INTRODUCTION

According to the World Meteorological Organization (WMO) and Food and Agriculture Organization (FAO), desert locust is one of the more than 10,000 short-horned species of grasshoppers (WMO and FAO, 2016). The government of India (GOI) document that the pest is naturally found in arid and semi-arid lands (ASAL) of northern Africa and southwest Asia (GOI, 2019). It is estimated that desert locust invasion can cover up to 31 million square kilometres during upsurges (WMO and FAO, 2016). In addition, a great amount of land sometimes as high as 20% of the earth's agricultural land can be affected by desert locust invasions during plagues (GOI, 2019). Desert locust can sometimes invade more than 29 million square kilometres, extending to about 60 countries across the globe (WMO and FAO, 2016). In north Africa, the middle-east, southwest Asia as well as western and eastern Africa, desert locust is considered a serious agricultural pest in more than 50 countries (Lecoq, 2019).

The changing biology, enhanced destructive behaviour and migratory patterns of desert locust during

gregarious phase are influenced by environmental factors such as precipitation, temperature, soil texture and moisture, condition of vegetation as well as wind direction and speed (Retkute et al., 2021). Management of desert locust upsurges and plagues is therefore complex due to biological, meteorological and geographical factors that play different roles within this integrated ecosystem. Due to this complexity, desert locust management as a national disaster is not only resource-demanding but it is also labour-intensive (Belayneh, 2005). Desert locust management as a multifaceted value chain encompasses surveillance activities, control operations and recovery programs.

Each of the desert locust management phases come with some challenges. For instance, Showler (2021) noted that insecurity and armed conflict are significant challenges of desert locust management in Asia and Africa. Showler reported that violent conflicts have the potential to deter surveillance and control activities by limiting access to affected areas. Showler also documented geographical remoteness and expansive landscape as other challenges during desert locust management. For example, some of the most important breeding habitats such as the expansive "Empty Quarter" in the Arabian Peninsula are of geographically inaccessible for continuous surveillance and preventive control (Hardeweg, 2001). This makes the area an important epicentre of many outbreaks as it promotes breeding in Yemen, Oman and Saudi Arabia.

To overcome the challenge of geographical remoteness and expansive landscape, the FAO Locust Pesticide Referee Group (LPRG) recommended use of ultra-low volume (ULV) formulated pesticides (FAO, 2021). However, Githae and Kuria (2021) found that ULV pesticides resulted in adverse effects on non-target organisms thus threatening the environment. This environmental risk is associated with use of hazardous petroleum products such as diesel, to carry the active ingredient in ULV pesticides, as a cheaper alternative to plant-based oils.

The FAO identified inadequate training of survey and spraying teams as a serious challenge in desert locust management operations globally (FAO, 2014; Showler, 2018). Notably, inadequate skills on surveillance could lead to submission of false-positive reports and poor delimitation of spraying sites. Such operational errors could in turn lead to aerial application of pesticides in human settlements and protected areas thus threatening people and wildlife. In addition, Kassegn and Endris (2021) documented that Covid-19 containment measures especially restricted movement and social distancing prevented group trainings in Ethiopia. This in turn slowed down the speed of creating a large pool of personnel with requisite skills to manage desert locusts.

Kenya was experiencing such a severe invasion of desert locust after 70 years. This meant that the country had limited financial, technical, physical and human resource capacity to deal with desert locust emergencies. Although aforementioned studies have identified some of the challenges during desert locust management in other parts of the world, they fall short of providing detailed account of challenges that Kenya experienced during the 2029-2021 invasion. In addition, the studies seldom evaluate the potential contributions of these challenges to other human security risks beyond food insecurity. These are major gaps that this study sought to address. These findings are useful to policy makers in guiding strategic planning for desert locust risk management. Disaster managers can also derive insights from the results of the study to increase preparedness against operational challenges, and thus enhance early response to protect food security against desert locust risks.

MATERIALS AND METHODS

The study employed ex-post facto evaluation and cross-sectional survey designs. This integration enabled retrospective evaluation of operational challenges and made sure respondents were drawn from diverse subgroups to reduce personal and institutional biases. The study site was Kenya as one of the countries that experienced the 2019-2022 upsurge in the east and horn of Africa region. Kenya was specifically unique because it is an invasion country that had not experienced such a devastating desert locust upsurge in her post-independence dispensation. The target population included people who were affected and/or participated in desert locust management.

The population included general public/community members, national government, county governments and international/non-governmental organisations (I/NGOs). Multi-stage approach using purposive and stratified sampling techniques were used to target a sample size of 900 respondents from 30 counties. Purpose sampling ensured that only individuals with the credible information were targeted to guarantee reliability of findings. Stratified sampling ensured that diverse clusters of respondents were included to reduce

biases that could lead to type 1 error. The respondents were invited to remotely fill a digitized online questionnaire using a web-based Kobocollect. Some 96 questionnaires were however excluded from analysis for lacking more than 75% of responses, while 28 were excluded as duplicates from respondents who had made more than one submission. After data-cleaning exercise, 779 questionnaires were considered for data analysis, representing 86.6% response rate.

Mixed methods concurrent approach was used in data collection where structured questionnaire and focus group discussion (FGD) were used to collect quantitative and qualitative data. Mixed methods allowed triangulation of data collection sources, tools and analysis for complementarity that ensured credibility of inferences. The questions in the questionnaire were framed in positive and negative constructs to safeguards validity of responses. Quantitative data was analysed through descriptive using frequencies and percentages and inferential statistics through ordinal logistic regression. The resultant Likert scale data were non-parametric thus only corresponding non-parametric tests such ordinal regression could have assessed cause-effect interaction without the risk of false-positive or false-negative inference. Qualitative data were analyzed using thematic analysis and brief quotes were included in the discussion to support statistical findings. Both quantitative and qualitative datasets were triangulated to provide corroborative discussion of the findings to sustain credibility of the conclusion.

RESULTS

Constructs of establishing challenges of desert locust risk management included insufficient tools and equipment, poor mobile phone signal, and limited internet connection. Other assessment criteria included inadequate training, limited knowledge and skills, poor communication, lack of clear leadership, inadequate information, poor supervision, and unclear division of roles. In addition, extreme weather and difficult landscape, insecurity, political interference and covid-19 containment measures were used to help in the assessment. Limited funds, and corruption, as well as refusal of communities to report desert locust presence, and withholding of empty pesticide containers were used to assess the challenges. Each category of desert locust management challenge was treated as a variable and was assessed by respondents on a 5-point Likert scale based on several constructs and the results are displayed in Figure 1.

Out of the 779 successful participants who responded to the study, 647 (83.0%) and 608 (78.0%) respondents agreed that difficult terrain and poor mobile phone signal respectively affected desert locust management. There were 589 (75.6%) and 584 (75.0%) participants who had opinion that insecurity and insufficient equipment respectively, hindered desert locust management. In addition, 582 (74.7%) and 571 (73.3%) respondents felt that limited funds and extreme weather respectively, affected desert locust management practices. There were also 562 (72.1%) and 549 (70.5%) participants who felt that poor communication and lack of clear leadership were challenges that interfered with desert locust management. From the total sample, 534 (68.6%) and 531 (68.2%) respondents agreed that inadequate information and limited internet connection respectively, were limitation that slowed down response to manage desert locusts.

There were also 476 (61.1%) and 450 (57.8%) participants who had opinion that limited expertise in terms of knowledge and skills as well as inadequate training among plant protection stakeholders reduced the chances of successful management of desert locusts. From the total number of successful participants, 445 (57.1%) and 442 (56.7%) respondents had opinion that under-reporting of desert locust presence and poor supervision respectively, affected effective management of desert locust. There were also 416 (53.4%) and 411 (52.7%) participants who had opinion that covid-19 containment measures and unclear division of roles among plant protection stakeholders reduced hindered desert locust management operations. Finally, 398 (51.1%), 390 (50.5%) and 261 (33.5%) respondents believed corruption, political interference, and withholding of empty pesticide containers by community members hampered desert locust management. Out of the 779 successful participants who responded to the study, 647 (83.0%) and 608 (78.0%) respondents agreed that difficult terrain and poor mobile phone signal respectively affected desert locust management. There were 589 (75.6%) and 584 (75.0%) participants who had opinion that insecurity and insufficient equipment respectively, hindered desert locust management. In addition, 582 (74.7%) and 571 (73.3%) respondents felt that limited funds and extreme weather respectively, affected desert locust management

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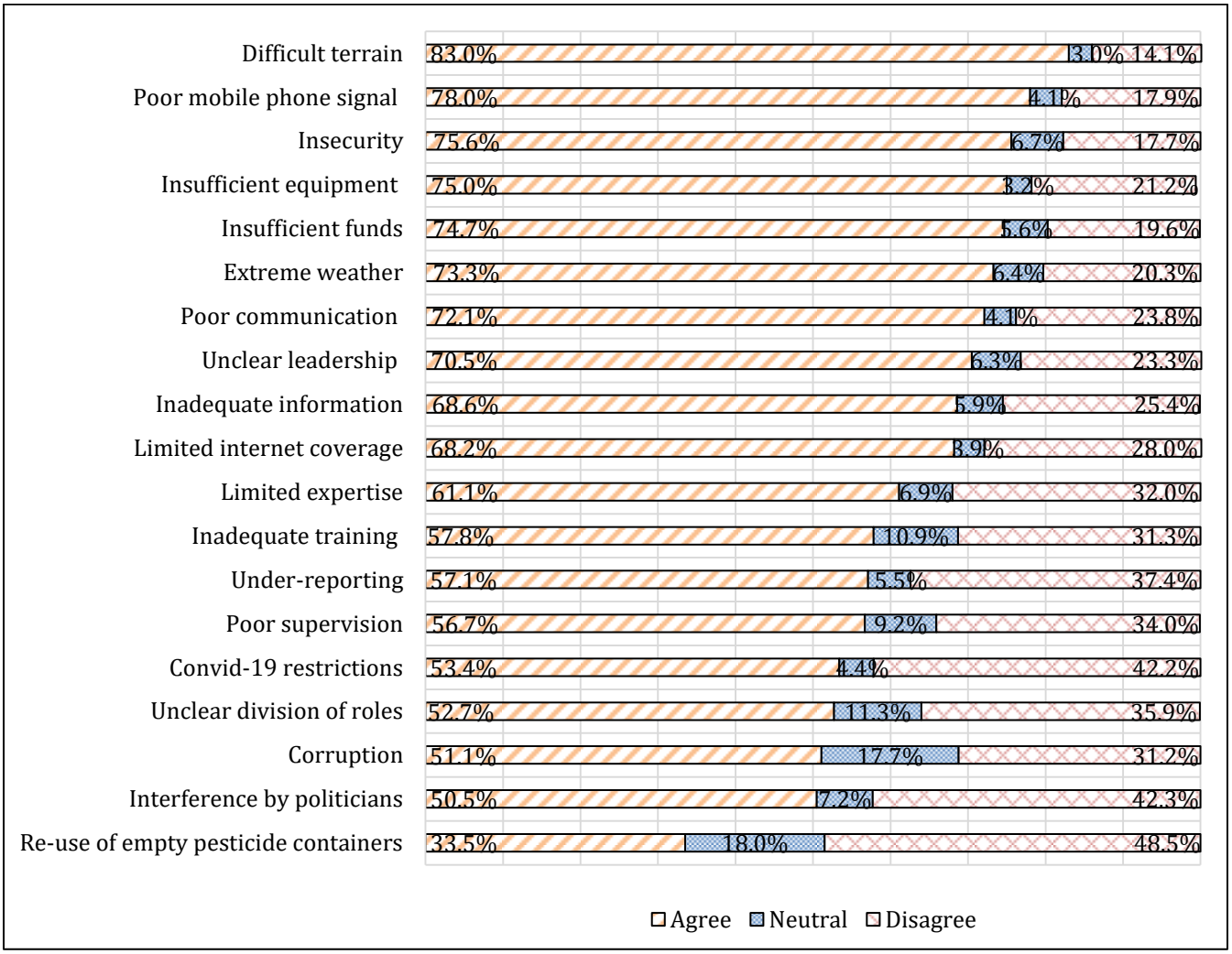

Figure 1. Percentage response to constructs of establishing challenges of desert locust management.

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To get deeper insights, constructs of evaluating desert locust management challenges were categorised as technical, human resource, coordination, geographical, political, financial and social-cultural challenges and the results are presented in Figure 2.

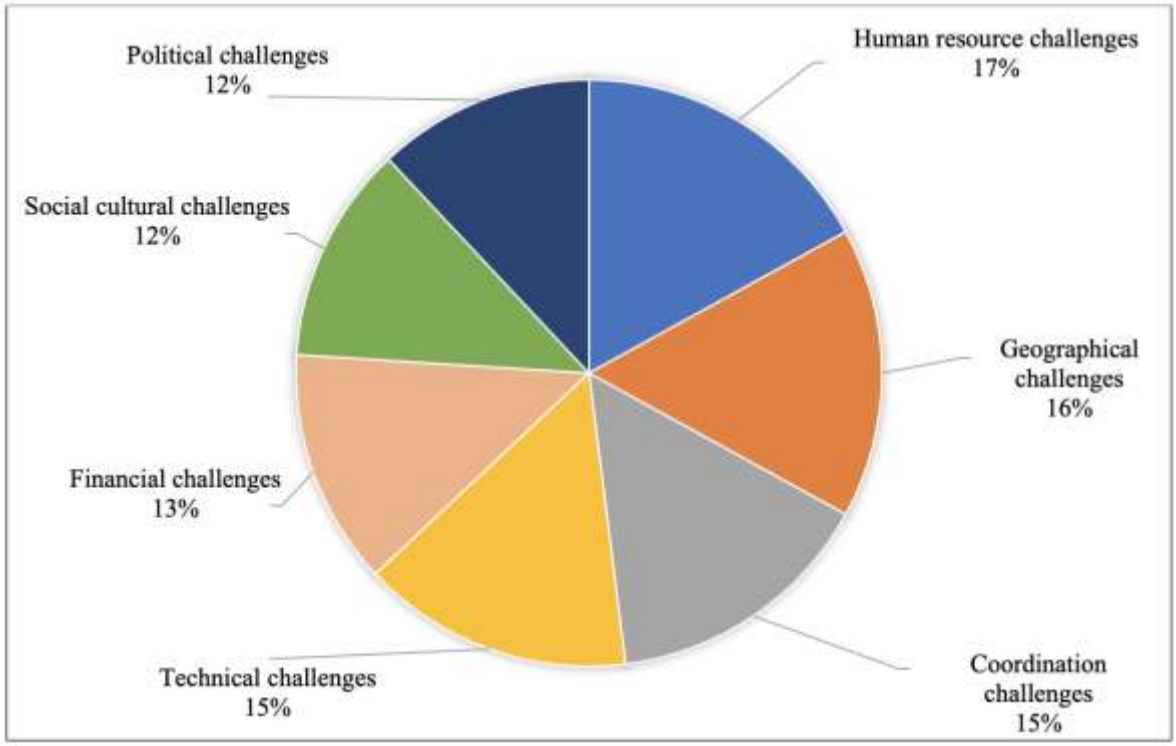

Figure 2. Percentage burden from desert locust management challenges.

Based on Figure 2, the findings revealed that human resource and geographical challenges had 17% and 16% hindrance to desert locust management, respectively. Technical and coordination challenges contributed 15% obstruction each; while financial limitations had 13% impediment. Political and sociocultural challenges contributed 12% hinderance each. Acknowledging the fact that descriptive statistics may not satisfactorily inspire conclusive inference, there was need to do inferential statistical test through regression analysis. As such, ordinal logistic regression was used to assess the extent to which each category of challenges contributed to limitation of desert locust management (Table 1).

After carrying out an ordinal logistic regression, the model fitting information showed statistical significance (χ^2 (7) =1329.54, p<0.001) indicating that there was a significant improvement in fit as compared to null model. The model therefore illustrated good fit for the research data. The goodness of fit information shows statistical insignificance (χ^2 (5625) =3940.14, p>1.000) thus the model fits the research data because there were no significant differences in the observed data and assumed model. The results of regression analysis are shown in Table 2.

Based on ordinal logistic regression test, all the odds for desert locust management challenges showed statistically significant results as follows (Table 2): Wald χ^2 (1) = 179.408, p <0.001 for human resource challenges, Wald χ^2 (1) = 165.276, p <0.001 for geographical challenges and Wald χ^2 (1) = 159.583, p

<0.001 for technical challenges. Wald χ^2 (1) = 147.999, p <0.001 for coordination challenges, Wald χ^2 (1) = 119.831, p <0.001 for financial challenges, Wald χ^2 (1) = 96.491, p <0.001for political challenges and Wald χ^2 (1) = 92.337, p <0.001 for social cultural challenges. These results revealed that human resource challenges created the highest obstruction to desert locust management operations while social cultural constraints had the least impediment. As such, any enhanced effort to address one or more of the desert locust management challenges could have had corresponding increase to effectiveness and efficiency of operations.

Table 1. Model fitting and goodness of fit information for challenges of desert locust management.

Model Fitting Information					Goodness-of-Fit			
Model	-2 Log Likelihood	Chi-Square	df	Sig.		Chi-Square	df	Sig.
Intercept only	2869.970				Pearson	3940.141	5625	1.000
Final	1540.427	1329.543	7	<0.001	Deviance	1540.427	5625	1.000

Table 2. Differentiated burden of various challenges to desert locust management.

Desert locust management challenges	Wald	Df	Sig	95% Confidence Interval		
				Exp_B	Lower	Upper
Human resource challenges	179.408	1	<0.001	2.757	2.377	3.196
Geographical challenges	165.276	1	<0.001	2.710	2.307	3.184
Technical challenges	159.583	1	<0.001	2.514	2.179	2.904
Coordination challenges	147.999	1	<0.001	2.447	2.136	2.807
Financial challenges	119.831	1	<0.001	2.119	1.818	2.472
Political challenges	96.491	1	<0.001	2.016	1.777	2.284
Social cultural challenges	92.337	1	<0.001	2.002	1.742	2.298

DISCUSSION

Desert locust management challenges were grouped into technical, human resource, coordination, geographical, political, financial and social-cultural constraints to guide the discussion.

Technical challenges during desert locust management

Technical challenges were evaluated based on insufficient tools and equipment, poor mobile phone signal, and limited internet connection. Out of the 779 participants who successfully responded to the study, 608 (78.0%) respondents felt that poor mobile phone signal hindered real-time reporting of desert locust presence. This in turn reduced opportunities for early warning, adequate preparedness and early action to control the pest. One participant expounded on this challenge asking “we were told to take a picture of locust and send to authorities. How could this happen if we usually have to go several kilometres to make emergency phone calls? There is only one hill in our village where mobile phones work”.

Absence of mobile phone signal in some remote locations as described in the above statement denied affected communities an opportunity for timely assistance. This could have exposed their crops and pasture to extended period of destruction by desert locusts. The challenge was common in many rural villages of the ASAL counties that were affected by desert locusts. Although the challenge could have been surmountable through deployment of satellite enabled-gadgets (FAO, 2020), this had an additional cost limitation as it required monthly prepaid subscription.

The mention of “we” in the above quote meant that anyone could report desert locust presence through mobile phones especially the eLocust3m application (FAO, 2021) that promoted crowd-sourcing of information. Crowd-sourcing through elocust3m allowed anyone with a smart-phone to download elocust3m on Play store for free, install it, and send desert locust presence reports to a centralized database in real-time. However, crowd-sourcing, had additional challenges as one information management officer complained saying “we could receive multiple reports from different people on the same location. People were

sending false-positive and false-negative reports of desert locusts. Others were reporting solitary locusts in central Kenya and reporting tree locusts and grasshoppers as desert locusts".

The above quote confirms challenges of duplication, misreporting and mixed reporting. False-positive reports where desert locusts were reported in areas the pest did not exist meant resources could have been wasted to carry out unnecessary confirmation search surveys. False-negative reports meant that desert locusts were not reported in areas where they were destroying crops and pasture and as such there could have been extended periods of devastation by the pest. In addition, misreporting and mixed reporting could have led to anxiety among people which could easily escalate to stress and depression (Saghir et al., 2018).

There were 584 (75.0%) participants who had opinion that insufficient equipment was a major hinderance to effective surveillance and control of desert locusts. One of the participants during national FGD explained: "There was only one old surveillance gadget in Kenya when desert locusts arrived in December 2019. The only eLocust3 tablet was not even in the hands of Kenyan government but Desert Locust Control Organization for Eastern Africa (DLCO-EA). Kenya could not rely on that one gadget to report desert locust that had invaded several counties. That is why a more accessible eLocust3m mobile app was developed to address this challenge".

The above quote demonstrates how underprepared Kenya was to manage desert locusts. The challenge of having only one surveillance gadget (eLocust3 tablet) meant that reporting was delayed and hence response to manage the pest was slow.

The destructive nature of desert locust means that a small swarm could destroy several metric tonnes of crops (FAO and WMO, 2016). Any time that was lost before control operations started could therefore have had proportionate negative effects on food security. The challenge of having only one surveillance gadget (eLocust3 tablet) was however a blessing in disguise because it triggered resilience-building. It led to the development of eLocust3m allowed people to send desert locust reports in real-time. The reports could then be analysed by the government and partner institutions to support precise and rapid control activities.

To reaffirm the challenges of desert locust control equipment, another participant noted during one of the county-based FGD: "We were surprised to see machine guns being used to spray desert locust".

The sentiments came as a surprise to the research team. It was however, clarified that the "machine gun" the respondent was referring to was a vehicle mounted sprayer (VMS). This was a relatively new equipment to the local communities in north-eastern parts of Kenya. However, their likening it with machine gun was valid because they are used to seeing security vehicles that are mounted with artillery equipment.

An agricultural officer, during the national FGD explained the limitation of equipment reporting: "There were only a few sprayers. Out of the few sprayers, some, such as knapsacks could not be used in desert-like areas where water to formulate EC pesticides was scarce. Through FAO, we got vehicle-mounted sprayers form Morocco to support ground control of desert locusts. Their faster work rate allowed us to cover up to 100 ha per day in open field with limited obstacles".

The statement shows that equipment such as sprayers were not only few but also unsuitable and impractical for use under some circumstances. The confirmation of support having had to come from as far as the farthest corner of northwest Africa also supports the desperate situation of preparedness that desert locust management encountered in Kenya. Interregional collaborations therefore played a critical role to enhance resilience by increasing physical capacity through supply of desert locust control equipment (GOK, 2022). Limited equipment meant that desert locust management work rate was slow and this could have created room for the pest to destroy more crops and pasture in the affected areas. The findings substantiate Showler et al. (2022) report that documented limited equipment and depletion of control material following many years of recession that lowered desert locust management capacity in India and Pakistan.

Other than ground spraying equipment, there was limited aerial spray support mechanism. The DLCO-EA has a regional mandate to control migratory pests in 9 member states of eastern and greater horn of Africa. Unexpected magnitude of the 2019-2022 upsurge was however overwhelming. One participant elucidated: "The few old but still serviceable sprayer aircrafts could not manage to carry out spray operations in all the affected countries. Individual countries had to come up with innovative ways of complementing regional

support structures by intervening on their own. We had to use military aircraft and land rovers; we mounted them with spray equipment, calibrated them and trained the pilots and drivers to spray appropriately. These innovations were very helpful in remote, hard-to-access and insecure areas. International community and development partners through FAO and the World Bank also supported Kenya by hiring private aircraft to undertake surveillance and control operations in collaboration with government plant protection officers".

From the above statement, it is clear that at regional level, aerial spray aircraft were few and old to serve the expansive eastern and horn of Africa region effectively. Use of military personnel and equipment by individual countries also indicate that ministries responsible for agriculture had insufficient aerial spraying equipment. Reliance on regional resources and equipment that were at the behest of ministries not directly responsible for desert locust management shows external means of resilience-building. This meant that there could have been delays in response providing the pest with additional time to destroy plants. Recognizing desert locusts' rapid reproductive rate, long-distance migration and indiscriminate devastation on vegetative biomass (Joshi et al., 2020), delayed control could have exacerbated desert locust risks to people and the environment. The findings align with Story et al. (2008) who noted that aerial control of desert locusts was hindered by limited availability of aircraft that were capable of spraying pesticides.

During the study, there were 531 (68.2%) respondents who agreed that limited internet connection made real-time reporting of desert locusts difficult. One community scout during county-based FGD complained: "We were expected to send locust reports using internet. How was this to happen if even making phone calls in my village is not possible?"

The above statement demonstrates that reporting was not only difficult through internet-based options but also through phone calls. It shows the desperate situation which some affected communities found themselves in while trying to seek help by reporting desert locust presence. With limited real-time opportunities to report desert locusts, there could have been delayed response which gave the pest additional time to pose food security threats by destroying crops and pasture.

The results from this study are sustained by Showler (2021) who documented limitation of equipment as a challenge that hindered effective management of desert locusts. This challenge was however resolved as one locust management expert reported during the national FGD: "Internet challenge was only prevalent during the initial stages of desert locust management in Kenya. Continuous improvement of the eLocust3m mobile application allowed offline filling of survey forms and retrospective submission of several reports upon access to internet signal. A satellite-enabled eLocust3g was also developed to support surveillance in areas with no mobile-phone signal".

The quote shows that there were urgent efforts to address challenges of monitoring and reporting desert locust presence. The speed with which some technical challenges were resolved as highlighted in the above quote, demonstrates some level of resilience-building to enhance effectiveness of desert locust management.

Geographical challenges during desert locust management

Geographical challenges were evaluated as per extreme weather, and difficult landscape. Out of the 779 participants who successfully responded to the study, 647 (83.0%) respondents felt that difficult geographical terrain affected survey and control activities. One of the pilots who participated in the national FGD advised: "It is not easy to spray locusts that are roosting between hills because turning is difficult, and maintaining a standard flight height for uniform pesticide application rate is compromised. Spray aircraft crushed in one of the neighbouring countries during the 2019-2022 upsurge due to some of these challenges."

This statement describes the complexity of carrying out aerial surveillance and control activities on difficult topography. This complexity meant that some desert locust infestation could have gone unreported. In addition, it meant that control operations could have been postponed awaiting desert locusts to move to safer spraying zones. Unreported incidents and delayed control meant that the pest continued to destroy crops and pasture thus exacerbating food insecurity.

The findings are supported by Gay et al. (2020), Showler et al. (2022), and Story et al. (2008) who reported that ground and aerial surveillance and spraying were made difficult by geographical remoteness as well as physical obstacles such as isolated stands of forest trees, power lines, property boundaries and administrative borders. Other than complicating surveillance and spray

operations, hilly landscape may put aircraft crew at risk of crushing (Hardeweg, 2001). Another participant reported fatalities emanating from geographical and weather challenges saying: "In 2021 when the invasion was still active, there was a report of an aircraft that crashed and killed a very experienced spray pilot on its way from Kenya to control desert locust in a neighboring country." The quote illustrates the life-threatening personal security risk that could emanate from geographical and weather challenges when aircraft operations are compromised.

The results of this study could easily be associated with Story et al. (2008) who found that in some areas, aircraft were forced to operate above the recommended 10 metres spraying height as a safety precaution to avoid unexpected obstacles. However, adjustment of spraying height, could have ended up compromising the pesticides application rate and ended up interfering with effectiveness of control operations. However, there has been deliberate efforts by desert locust management organizations to introduce unmanned aerial vehicles (UAVs) in surveillance and control operations to build resilience against such challenges (Matthews, 2021; Alemu and Neigh, 2022).

There were 571 (73.3%) respondents who agreed that extreme weather affected desert locust management operations. Cloudy weather could have reduced visibility of surveillance teams and complicated flight navigation for aerial spraying. One of the national FGD participants narrated: "We had to cancel spray operations several times due to cloudy weather. There is one incident when rain fell unexpectedly after spraying part of a medium-size swarm. The swarm split into multiple smaller swarmlets and tracking them for follow-up control was very hard."

The above quote demonstrates there was fear of safety risks when conducting desert locust control in cloudy weather. In addition, the statement confirms that rainfall caused an abrupt interruption of control operation and this could have led to dilution of the pesticide. Both stoppage of control as a safety precaution and dilution of pesticide show ineffectiveness of desert locust management due to extreme weather. The findings are in line with the results of Story et al. (2008) that found that ground and aerial spraying was difficult due to bad weather. Splitting of one swarm into multiple smaller ones as explained in the quote also meant that more resources would be required to trace, track and control them leading to economic insecurity from additional cost. The smaller swarms could also have moved in different directions and taken longer to find. This could have exposed more people in additional locations to food security risks.

Coordination challenges during desert locust management

Coordination challenges were evaluated in terms of poor communication, lack of clear leadership, inadequate information, poor supervision and unclear division of roles. Out of the 779 participants who successfully responded to the study, 562 (72.1%) and 534 (68.6%) agreed that poor communication and inadequate information, respectively affected effectiveness and efficiency of desert locust management. Ineffective and inefficient of desert locust management meant that protection of food security was jeopardized. One of the county-based FGD participants complained: "We collected a lot of data during desert locust survey operations but we did not know where this information was going to after online submission; we did not even get feedback concerning our reports."

The concern that was raised in this statement pointed to poor communication especially lack of feedback mechanism. Poor communication and inadequate information could have led to delayed and ineffective control of the pest. Delayed control certainly had direct effect on food security as the pest had more time to destroy crops and pasture that are a source of livelihood to people in the affected areas. In addition, limited feedback could have resulted in misunderstanding and anxiety among people which could lead to personal insecurity by causing anger and despair (Saghir et al., 2018).

Kenya had not experienced such a severe desert locust invasion by for long time despite having reported some incidents in the first decade of the current century. As a result, there was limited structured way of communication among desert locust management stakeholders. For instance, one participant during national FGD reported: "The data that was collected during surveillance was submitted to multiple third-party databases outside the country due to limited technical capacity to manage desert locust information in Kenya. The situation however changed rapidly with the establishment of an information office in Kenya that was linked to the global desert locust information service that coordinates surveillance,

forecasting and early warning in 30 countries across Africa and Asia. Today, Kenya has all the desert locust reports that were collected withing the country during the 2019-2021 upsurge."

The narrative describes lack of information management autonomy by Kenya at the start of the recent upsurge. This could have compromised both validity and reliability of decisions made from foreign processed information making desert locust management inefficient. Inefficiency in desert locust management meant that more resources than expected could have been used leading to direct effect on economic security. The findings are corroborated by results of Showler et al. (2021) that documented coordination as a challenge during desert locust management. The narrative also describes how extreme efforts were made to build resilience by addressing emerging challenges as promptly.

There were 549 (70.5%), 442 (56.7%) and 411 (52.7%) respondents who felt that lack of clear leadership, poor supervision and unclear division of roles respectively, made desert locust management difficult. One of the FGD participants jokingly said: "Desert locust management turned into a lucrative crisis's economy; everyone wanted to take the lead. I think the motivation was control of financial flow as there was heavy funding. However, through the emergency locust response program, a national locust control unit and similar units at county levels were established to coordinate surveillance, control and recovery activities."

This statement at face value points to some vested interests other than protection of food security by reducing desert locust risks. Everyone wanting to lead meant there was unclear leadership and improper division of roles. In such circumstances, decision-making could have taken longer. In addition, holding people and institutions accountable could have been difficult. This could have led to slow action as no-one could have felt outrightly responsible.

Delayed action to control desert locust meant that the pest continued to destroy crops, pasture and other plants thus exposing the country to food and environmental insecurity. The quote also reveals there was unstructured modus operandi that could have left vacuums where interested parties found entry points to pursue their personal or organizational ambitions. In pursuit of personal interests, inefficiency could have emerged through misappropriation of resources which has impact on economic security. The findings of this study resonate with the report of Showler et al., (2021) who traced the need for coordination in desert locust management as far back to the 5th International Locust Conference of 1938. However, the quote also indicates there were initiatives to build resilience through establishment of national and county locust management units.

Financial challenges during desert locust management

Financial challenges were evaluated based on limited funds and corruption through misappropriation of mobilised resources. Out of the 779 participants who successfully responded to the study, 582 (74.7%) agreed that limited funds were a serious challenge to desert locust management. Limited financial resources and misappropriation of funds could slow down response to manage desert locusts. One of the FGD participants explained the financial difficulties experienced during desert locust management saying: "The government had to get a loan facility from the World Bank to support desert locust management because such expenditure had not been projected in the national budget."

This statement shows there was a budgetary constraint at national government to facilitate desert locust management. Both surveillance and control of desert locusts require funds to procure equipment and facilitate field activities. Limited financial resources therefore meant management of desert locust was not as rapid and effective as it should be.

Remember that a one-day delay in managing a small swarm of desert locusts could lead to loss of food adequate to feed 35,000 people (WMO and FAO, 2016). Delays emanating from financial challenges could therefore have exacerbated food security risks from desert locusts due to slow response to manage the pest. These findings are closely associated with results of Thompson and Miers (2002) who documented that most desert locust affected countries relied on international assistance to fund surveillance, control and recovery programs due to government's financial constraints. One state officer expounded on this during the national FGD saying: "Desert locust invasion started midway the financial year and therefore national and county governments hardly had any specific budgetary allocation for management of the pest. There was also limited time for re-allocations through the legislative process of supplementary budget."

The statement demonstrates the financial complexity that Kenya found herself in during the 2019-2021 desert locust invasion. To expound on how severe financial challenges could affect desert locust management, it is important to note that most recession and invasion countries fall within World Banks's developing countries categorisation. As such, they have limited monetary reserves to deal with natural disasters such as desert locust upsurges and plagues (Kassegn and Endris, 2021). The findings are upheld by Showler (2003) who recognized insufficient funding for desert locust control operations as a major challenge. The initiative of the Government of Kenya to secure a loan from World Bank points to external resilience-building mechanism that ensured fast response, reduced crop losses and supported livelihood recovery.

There were 398 (51.1%) respondents who felt that corruption was one of the challenges during desert locust management in Kenya. One of the participants noted: "Recovery programs by different organizations were sometimes targeting the same beneficiaries. Some people reaped big and made good fortunes from desert locust recovery programs."

Receiving of multiple benefits from different entities for the same problem as described in the above quote is a classic example of corruption. Corruption leads to inefficiency in resource utilization (Hajilee et al., 2021), and this could have had led to economic insecurity. In addition, when some people benefit several times for the same problem at the expense of other potential beneficiaries, it creates inequality and this could pose personal security risks such as social exclusion.

Human resource challenges during desert locust management

Human resource challenges were evaluated based on inadequate training as well as limited knowledge and skills among desert locust management personnel. Out of the 779 successful participants who successfully responded to the study, 476 (61.1%) respondents cited limited expertise in terms of knowledge and skills as a challenge during desert locust management. Kenya had not experienced desert locust invasion of a similar magnitude for several decades (FAO, 2020). As such, the field of desert locust management could neither have attracted many scholars nor practitioners. One participant during the national FGD jokingly commented: "Everyone became an entomologist. As if that was not enough, everybody suddenly turned into a desert locust expert. Even having a critical mass of people with basic skills especially safe use of pesticides and effective spraying was not possible."

This statement in reality means there were limited number of desert locust experts in Kenya when the first wave of invasions was reported in 2019. Limited knowledge and skills meant that effectiveness of desert locust management was not assured. As such, protection of food security from desert locust risks was not guaranteed. In addition, limited expertise created space for anyone with crop protection, plant pathology and entomology background to try and step in to contribute to desert locust management.

While everyone's contribution may have helped to generate valuable ideas on how to kickstart desert locust management campaign, it complicated coordination mechanism. Having few people with basic skills on safe use of pesticides and effective spraying meant that health and environmental security risks were inevitable. The findings reverberate with publication by Showler et al. (2022) who reported that human resource constraint is a major challenge in desert locust management during upsurges and plagues. Showler linked this challenge with erosion of institutional memory due to staff turnover after retirement and redeployment following many years of remission period in India and Pakistan.

One agricultural officer expounded on the challenge of limited technical staff to support desert locust management field operations saying: "There was no time to waste in trying to experiment locally on how best to control the pest. We had to use the military and NYS members because they were easy to mobilise and they were also very responsive to instructions."

Use of paramilitary service members as described above indicates there was need for reinforcement of the mainstream plant protection officers due to their low numbers. However, presence of security agents especially soldiers among community members created fear and anxiety which have health security risks associated with psychosocial instability. The military and NYS members had limited pesticide handing skills and this could have posed them to health security risks. The findings are supported by Showler (2021) who documented poor field practical skills due to inadequate training as a challenge to effective management of desert locusts. However, use of security officers who could be deployed rapidly to support desert locust management was resilience-building strategies to reduce response

time thus safeguard food security against desert locusts.

There were 450 (57.8%) respondents who had opinion that inadequate training among plant protection stakeholders was a challenge during desert locust management. With limited expertise in the country, there was need to import expatriates with requisite knowledge and skills on desert locust management from recession countries to support capacity building. One participant during the national FGD said: "Bringing in people with first-hand experience on desert locust management from other countries was seen as a solution to limited local expertise. Initially, we had to bring in a geospatial mapping expert from Mauritania and spray experts from Morocco, Germany and Australia to support desert locust management."

Reports of inviting international experts as described in the above statement demonstrate there were limited desert locust management experts in Kenya. With limited resources to procure equipment and facilitate field personnel as aforementioned, sourcing for expatriates could only have worsened the economic insecurity that desert locusts were causing. The findings are in agreement with Showler et al., (2021), who noted that the most common challenge during desert locust management has to do with limited access to requisite knowledge. External expert support was however a resilience-enhancing approach to reduce delays in the management of desert locusts and reduce negative effects from the pest.

Political challenges during desert locust management

Political challenges were evaluated in terms of insecurity, political interference and covid-19 containment measures. There were 589 (75.6%) respondents who agreed that insecurity was a major challenge during desert locust management. One of the agricultural officers during county-based FGD elaborated this stating: "During one of the locust surveillance exercises, a local chief warned us not to proceed beyond some valley. He claimed that the valley was a cattle rustlers' hideout and anyone who dared to get in the valley could not be found alive."

During the national FGD, another respondent stated: "The national desert locust management team had to train special technical teams that were drawn from county directorates of agriculture. These teams were based in counties that have proximity to Al-Shabab-prone neighbouring country. In addition, aerial control of desert locust in the insecure areas was done using military aircraft."

The first quote shows that insecurity was a barrier to desert locust operations in some places. Insecurity could have slowed down surveillance and control operations thereby giving the pest more time to continue destroying vegetation and hence exacerbate human insecurity. In addition, insecurity could have allowed the pest to breed and increase the pest population which would mean more destruction to crops and pasture. Increased pest population would also need additional resources to manage which would lead to increased economic insecurity. The findings are in tandem with a study by Gay et al. (2020) who reported insecurity could deter surveillance and control, facilitate further breeding, cause outbreak development into upsurges and lead to invasions in neighbouring countries. The second quote illustrates the strategies that were used to create resilience against challenges of insecurity.

There were 416 (53.4%) respondents who felt that covid-19 containment measures were a challenge to most desert locust management activities especially awareness creation, public sensitization, training, surveillance and control. One of the filed control base managers contributed to this discussion during national FGD saying: "Early stages of the invasion coincided with the onset of Covid-19 pandemic in the country that led to suspension of international flights. This made support by regional and international trainers difficult. The paradigm-shift from face-to-face to online virtual trainings created a new channel for capacity development. However, online trainings had limited opportunities for learning-by-doing that is critical for tactical level interventions such as hands-on practical skills in desert locust survey and control."

The above statement confirms how Covid-19 containment restrictions made an already bad desert locust situation worse. Interference with awareness creation, public sensitization and trainings by covid-19 containment measures especially restricted movement and social distancing meant that surveillance and control activities were slowed down. Delayed surveillance and control operations due to covid-19 containment measures meant that desert locust had more time to destroy crops and pasture thus worsening food insecurity. The findings concur with Kassegn and Endris (2021) who found that Covid-19 containment measures especially lockdown and social distancing prevented

group trainings and hence exacerbated desert locust risks in Ethiopia. Use of online training channels however provided a resilient capacity development option to address the challenge.

Out of all participants who responded to the study, 390 (50.5%) respondents agreed that political interference made desert locust management complex. One officer gave a detailed account of how politics can interfere with desert locust management saying: "We were detained for 4 hours in a neighbouring country during an aerial surveillance exercise."

The quote indicates that political circumstances such as international boundaries could interfere with effective management of desert locusts. The heavy-feeding and long-distance migratory behaviour of desert locusts (GOI, 2019; WMO and FAO, 2016), meant that every lost time could have worsened food security risks resulting from the pest. For a pest that can migrate 16-19 kilometres in an hour (Symmons and Cressman, 2001), a four-hour detention of a surveillance team that was tracking a swarm would mean losing sight of the pest. Losing track of a swarm would give it more time to destroy crops and pasture thus exacerbating its threat to food security. The results are in congruence with findings of Story et al. (2008) who reported that ground and aerial spraying could be affected by political boundaries.

Internal politics of devolved governance in Kenya were also at play and could have affected desert locust management albeit at smaller scale. For instance, one county government official questioned: "Why could not the national government give us the money to spray locusts ourselves instead of running all over the country like we did not exist?"

This question illustrates there was political disquiet where counties felt that it was their responsibility to manage desert locusts. The rapid migratory habit of desert locusts (GOI, 2019), and lack of cross-county mandate by individual devolved governments (GOK, 2010) meant that if counties were left to manage the pest, food security risks could have increased. This is drawn from the fact that a swarm that was reported in one county in the morning could be tracked in a different county in the evening, and get sprayed in a third county the following day (GOK, 2022). If the national government was not involved, and one or more counties were unable to control desert locusts, there could have been transfer of food security risks to several other counties.

Social-cultural challenges during desert locust management

Social-cultural challenges were evaluated as per refusal of communities to report desert locust presence, and withholding of empty pesticide containers by people. Out of the 779 successful participants who successfully responded to the study, 445 (57.1%) respondents had opinion that under-reporting of desert locust presence curtailed effectiveness of desert locust management. One respondent explained why they refused to report desert locusts asking: "Why would we report desert locusts to be killed and they brought rains and bumper harvest? It is even written in the Bible that what locusts eat would be brought back multiple-folds."

While this belief sounds mythical, it could have had negative ramifications on the effectiveness of desert locust management. Under-reporting of desert locust meant that the pest continued to destroy crops, pasture and other plants. In addition, failure to report could have allowed desert locust to breed and increase their population. This could in turn amplify desert locust risks to food and economic security.

There were 261 (33.5%) respondents who felt that withholding of empty pesticide containers by community members was one of the challenges during desert locust management. A respondent justified this kind of behavior stating: "Why would the government want to collect the drums and they were bought using our taxes? The drums are very strong and could make very nice jikos, doors and gates."

"Jiko" is Swahili word for charcoal-fuelled cooking stove. The quote indicates that members of the community felt entitled to retain the empty pesticide containers after desert locust control. This statement points to some level of oblivion among community members of the health and environmental security risks that pesticides residues could pose if empty containers are reused for storage of food and water. In addition, the idea that empty pesticide containers could be used for fabrication of other items meant that people could confiscate them instead of surrendering them for cleaning, crashing and safe disposal. This could expose people to pesticide residues that are hazardous to human health and the environment. The findings are supported by Showler (2021) who noted there has been a serious problem of dealing with empty pesticide containers as there is high demand by the public to reuse them which poses health

and environmental security risks. During the national FGD, one expert from a neighbouring country reported an incident where pesticides were poured and metallic drums were stolen by the locals.

CONCLUSION

This concludes that challenges during desert locust exacerbated not only food and economic insecurity but stretched into human security dimensions such as environmental, health and personal risks. The results revealed that human resource challenges created the highest burden to desert locust management. However, efforts to address these challenges enhanced Kenya preparedness in desert locust management by building short- and long-term resilience through establishment of operational structures, enhanced collaborations, technological innovations as well as physical and human capacity development. Due to realization that desert locust management challenges can exacerbate human security risks, the study recommends continuous capacity development through regular maintenance of equipment, continuous training of personnel and periodic update of preparedness plans.

AUTHORS' CONTRIBUTION

GEB did the research work including data collection and drafting the article as part of his PhD program; AMS and GOO supervised the research study, reviewed and edited the article.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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