Desert Locust Information Service

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Africa / Middle East / Asia I Food Security / Agriculture

INTRODUCTION

The desert locust (Schistocerca gregaria, Forskål) is the oldest and most feared of all migratory pests in the world, and is well known among farmers, nomads, and locals living in arid and semi-arid regions between West Africa and India. Its presence in Egypt has been documented during Phaoronic times some 5,000 years ago, and is mentioned in both the Bible and the Koran. Under normal conditions, low numbers of individual solitary adults are present within a vast desert area: roughly 16 million km2 in nearly two dozen countries extending across northern Africa, the Middle East, and southwestern Asia.

In order to minimize the frequency of desert locust plagues and their associated food losses, locust-affected countries and the Food and Agriculture Organization (FAO) of the United Nations (UN) have adopted a preventive control strategy that relies on early warning and early reaction. The FAO Desert Locust Information Service (FAO DLIS) operates an early warning system that monitors weather, ecological conditions, and locust infestations in the potentially affected area on a daily basis.

Since 1975, FAO FAO DLIS has issued a monthly bulletin to locust-affected countries, the international donor community, researchers, institutes, and other interested parties that summarizes the current situation and provides a six-week forecast on a per-country basis. During periods of increased locust activity, FAO FAO DLIS issues alerts and warnings directly to affected countries and helps to organize emergency control campaigns. These products are the main deliverables of the FAO FAO DLIS early warning system and are part of the global strategy to prevent plagues.

Information provided by FAO DLIS to National Locust Centres (NLCs) is used to plan survey and control operations in the field and prepare for swarm invasions by pre-positioning resources and teams. If the information provided by FAO DLIS is both precise and timely, field operations will potentially be more effective and costs can be decreased.

SOCIOECONOMIC BACKGROUND

Increased populations of desert locusts can damage subsistence crops, pastures, irrigated agricultural areas, and export cash crops, threatening the food security and economic prosperity of affected countries and regions. One tonne of locusts, a very small part of the average swarm, can consume as much food in one day as 2,500 people. In most of the affected region, farming systems are already naturally vulnerable and cannot sustain additional stress or disruption posed by desert locust infestations. This fragility could be exacerbated if temperatures become warmer and rainfall decreases in potentially affected areas.

One quarter of the world's population lives in an at-risk region and during a locust plague, nearly one-third of the world's inhabitants can be affected by the growth and movement of locust swarms. An average-sized swarm contains billions of insects and can easily cover New York City. In one day, such a swarm can eat the same amount of food as the entire population of both New York and Pennsylvania (roughly 32 million people). It is not uncommon for a small swarm to wipe out a farmer's field and his entire livelihood in less than a morning. In 2003-05, it took almost a half billion dollars to bring the last regional plague in West Africa under control. Nearly half of the money came from the affected countries themselves, many of which have inadequate national budgets for schools, clean water, electricity, communications, roads, and other infrastructure. Nearly $100 million was devoted to food aid alone and more than 13 million hectares were treated in a total of 23 countries. Despite the large sums of money spent on control operations, crop damage in West Africa amounted to 80-100% loss of cereals, 85-90% loss of legumes, and 33-85% loss of pastures. In Mauritania, some 60% of the household heads became indebted because of locusts; in Mali and Burkina Faso, 45% and 33% of household heads were indebted because of desert locusts respectively.

TARGET AUDIENCE

The primary recipients of the FAO early warning system are the NLCs, which are autonomous or semi-autonomous governmental units within the Ministry of Agriculture Plant Protection Departments of Afghanistan, Algeria, Bahrain, Burkina Faso, Chad, Djibouti, Egypt, Eritrea, Ethiopia, India, Iran, Iraq, Israel, Jordan, Kenya, Kuwait, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Pakistan, Qatar, Saudi Arabia, Senegal, Somalia, Sudan, Syria, Tunisia, the United Arab Emirates (UAE), and Yemen.

The FAO FAO DLIS products also reach institutions in the following sectors:

International donor community:

- United States Agency for International Development (USAID)
- World Bank
- African Development Bank
- Islamic Development Bank
- European Community (EC)
- Canadian International Development Agency (CIDA)
- Japan International Cooperation Agency (JICA)
- UK Department for International Development's (DFID) Official Development Assistance (ODA)
- Belgium, Finland, France, Germany, Norway, Spain, Sweden, Switzerland, The Netherlands

Researchers community:

- Oxford University, UK
- Pennsylvania State University, USA
- University of Edinburgh, UK
- Columbia University, USA
- Wageningen University, Netherlands
- Université catholique de Louvain, Belgium
- University of Wyoming, USA
- University of Sydney, Australia

Institutes:

- International Centre of Insect Physiology and Ecology (ICIPE), Kenya
- Agricultural Research for Development (CIRAD), France
- Australian Plague Locust Commission (APLC)
- The Desert Locust Control Organization for Eastern Africa (DLCO-EA)
- International Red Locust Control Organization for Central and Southern Africa (IRLCO_CSA)

CLIMATE AND CONTEXTUAL BACKGROUND

Weather is a key factor that influences desert locust numbers, population dynamics, and habitat-wide distribution. Rainfall is essential to desert locust populations because it creates the moist soil that females need to lay their eggs while also allowing for green vegetation growth, which nourishes and shelters locusts. Meanwhile, warm temperatures are important for egg development, locust maturation, and adult flight and migration. Contrary to other locust and grasshopper species, desert locusts produce many generations each year. Under optimal conditions, desert locusts live for about three months and can increase in number from one generation to the next by about 16 times (that is roughly a 65,000-fold population increase annually).

Adult locusts migrate with the wind as passive fliers up to about 1,800 meters above the ground, moving downwind at roughly the wind speed. Solitary adults fly at night while swarms migrate during the day. Downwind displacement of up to about 200 km per day tends to carry locusts into seasonal rainfall areas.

Desert locusts also change their behaviour, physiology, colour, and shape in response to environmental conditions[1]. Locusts are normally present at low densities in semi-arid or arid regions away from major cropping areas. They do not pose a significant threat to agriculture, and hopper bands and swarms are rare or completely absent. This calm period is called a recession. When the population level is low, a locust behaves as an isolated individual (solitary phase).

The transition from a recession to a plague is characterized by outbreaks and upsurges. An outbreak occurs when there is an increase in locust numbers over several months in a relatively small, localized area. At high numbers, a locust behaves as part of a single mass (gregarious phase). The intermediate phase between solitary and gregarious is called transiens. Three processes are involved in phase transformation: concentration, multiplication, and gregarization.

Scattered locusts will concentrate in green vegetation in response to habitat conditions and as a result of convergent winds. As locust numbers increase, individuals form small groups. Grouping can be considered as an intermediate step in the change from solitary hoppers and adults to gregarious hopper bands and adult swarms. If sufficient numbers of locusts are present and the outbreak continues, or if good rains fall and there is another generation of breeding, locust numbers will increase rapidly and small groups of hoppers and adults, hopper bands, and adult swarms can form.

If an outbreak is not controlled and if rain is plentiful, locusts will continue to multiply, concentrate, and gregarize. With each additional generation, the proportion of the total population in bands and swarms increases. This is referred to as an upsurge. If an upsurge is not controlled and further rains fall, then a plague can develop on a regional or continental scale, affecting up to 50 countries.

CLIMATE INFORMATION

FAO DLIS relies on field data collected by national teams associated with the NLCs during locust survey and control operations (Figure 1). Data, including observations of vegetation, soil, and locust populations, is recorded in a handheld, touch-screen data logger (eLocust2) that is connected to the GPS satellite system so that each survey and control location can be geo-referenced. The data logger is also connected to the International Maritime Satellite Organisation (Inmarsat) satellite system, which allows data to be transmitted in real time to the NLC in each country.

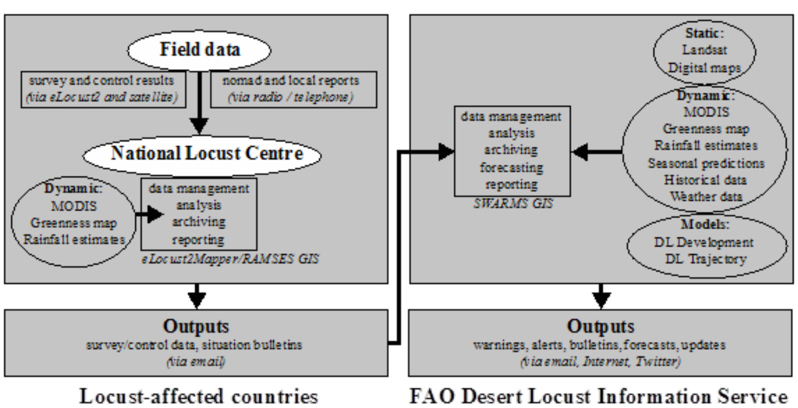

Figure 1. The locust early warning network of field observations (from national survey and control teams) transmitted in real time by satellite to NLCs (for data analysis in the RAMSES GIS) and forwarded to FAO DLIS (where global-scale analysis and forecasting are undertaken).

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[1] http://www.fao.org/ag/locusts/common/ecg/347_en_DLG1e.pdf

FAO DLIS also incorporates several climate-based products into the early warning:

1. Rainfall estimates and station data

Given that ecological conditions and locust populations are a function of rainfall, NLCs in locust-affected countries are most concerned with knowing where it has rained in the desert. FAO DLIS relies on a satellite-based rainfall estimate product provided at no cost by Columbia University's International Research Institute for Climate and Society (IRI) (Figure 2).

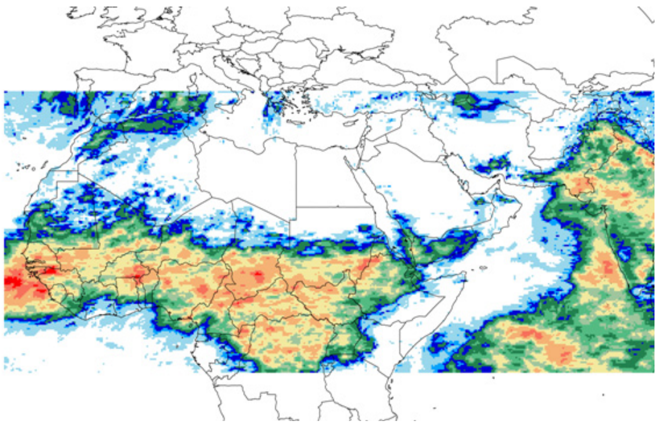

Figure 2: Satellite-derived geo-referenced rainfall estimates are used on a daily, decadal and monthly basis to estimate the spatial and temporal distribution of rainfall in the desert locust recession area; warmer colors indicate greater amounts of rain (example: August 2011).

Satellite-based estimates, which are better in determining the spatial distribution of rainfall than model-based estimates, are the most appropriate product for desert locust monitoring and early warning. The geo-referenced rainfall estimate is available as a daily, decadal and monthly product on a 0.25 x 0.25 latitude/longitude grid from passive microwave and infrared data at high spatial and temporal resolution. This data is based on the US National Oceanic and Atmospheric Administration's (NOAA) Climate Prediction Center (CPC) morphing technique (CMORPH) algorithm, which is a robust methodology that is specifically fine-tuned for arid areas. The rainfall estimate products were developed in collaboration with FAO DLIS. NLCs and FAO DLIS download these products on an operational basis from the freely accessible IRI website and incorporate them into their respective geographic information systems for analysis. FAO DLIS has an automated system that polls the IRI servers and downloads new products to the FAO server as soon as they become available.

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The IRI rainfall estimate is probably the single most useful climate product for locust-affected countries: The product is easy to download due to a very intuitive, web-based user interface. It is easy to interpret, and files are small enough that users are able to download them despite the slow or erratic Internet connections that are common in many locust-affected countries.

In addition to satellite information, limited precipitation stations are also used to track rainfall in the region. FAO DLIS uses NOAA station data, which is automatically downloaded every day from the Internet and added to a database for use in the Schistocerca Warning and Management System Geographic Information System (SWARMS GIS). However, station coverage in all locust-affected countries is insufficient to provide a complete picture. Rainfall estimates must instead be used, while station data can, at best, confirm some of the approximations.

2. MODIS satellite imagery

At present, 250-metre resolution Moderate Resolution Imaging Spectroradiometer (MODIS) imagery and its derivatives (Normalized Difference Vegetation Index, NDVI, and Enhanced Vegetation Index, EVI) are used to determine the location of green vegetation in desert locust habitats between West Africa and India (Figure 3).

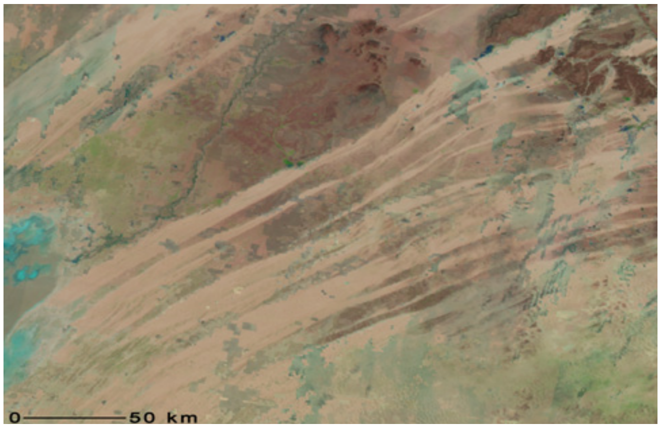

Figure 3: MODIS imagery is used every 16 days to estimate the spatial distribution of green vegetation in the desert locust recession area (example: western Mauritania, October 2010).

The images are available every 16 days, which is sufficient to detect changes in ecological conditions, i.e., annual vegetation that is either getting greener or drying out. Based on specifications provided by FAO DLIS, IRI developed a freely accessible website that makes MODIS imagery covering the desert locust recession area available to the NLCs at no cost. NLCs download the image for their particular country from the IRI website and import it into another GIS-based information technology program, Reconnaissance and Management System of the Environment of Schistocerca (RAMSES), for analysis. FAO DLIS also uses imagery for the entire recession area, which is automatically downloaded from the IRI server to the FAO server and analyzed with SWARMS.

There are three primary drawbacks to using MODIS imagery. First, the file size is often too large to be downloaded by locust-affected countries that have slow and erratic Internet connections. Therefore, users must zoom into smaller areas of interest and download each portion of MODIS one at a time, which can be difficult to manage. Second, it is difficult to interpret MODIS and determine those areas where annual vegetation may be green and suitable for desert locusts. Third, the sparse annual vegetation that is green or just becoming green is difficult to detect reliably due to sensor limitations. These omission errors are of considerable concern and limit the usefulness of MODIS for monitoring conditions in the desert locust breeding areas. Nevertheless, this is the best possible imagery available at present for monitoring vegetation. Many of these shortcomings are likely to be overcome with the next generation of vegetation monitoring satellites.

3. Greenness dynamic maps

In early 2011, a new MODIS-derived product became operational. These dynamic greenness maps include both spatial and temporal information to show changes over time in vegetation conditions (Figure 4).

A new algorithm was developed by the Université catholique de Louvain (Belgium) that involves the fine discrimination of NDVI and hue values. This method employs mean compositioning to minimize cloud contamination and reduce variations in reflectance values due to image acquisition with varying geometries. The Flemish Institute for Technological Research (VITO, Belgium) is responsible for incorporating research results into an operational processing chain and making the imagery available to end-users every ten days. VITO applies the algorithm to 250-metre resolution MODIS imagery, which is then re-projected. The color space is transformed from red, green, blue (RGB) to hue, saturation, and value (HSV). The resulting map indicates the evolution of vegetation development for the previous eleven decades (i.e., eleven periods of ten days each) for each 250-metre pixel, displayed in shades of red, orange, and green. The eleven-decade period corresponds roughly to the length of one locust generation.

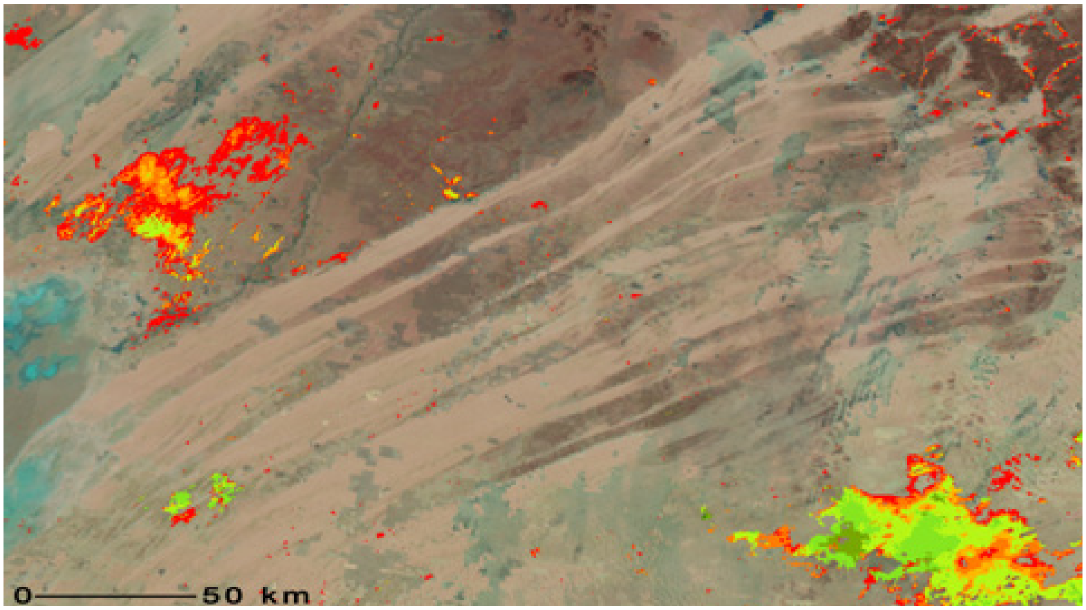

Figure 4: Dynamic greenness maps are used every ten days to determine how long vegetation has been green in the desert locust recession area (example: western Mauritania, October 2010 where warmer colors indicate newly green vegetation).

The greenness maps inform the user of the spatial and temporal variations in green vegetation and allude to rainfall distribution insofar as it reflects vegetation development. This allows for the identification of both the onset of green vegetation and ephemeral vegetation (false starts), and the disappearance of vegetation at the end of its developmental cycle. The maps also indicate the location of evergreen vegetation, which is of less importance to the desert locust. Greenness maps are disseminated at no cost by VITO through the password protected Group on Earth Observations' DevCoCast website. NLCs and FAO DLIS download the geo-referenced greenness maps and incorporate them into their respective geographic information systems for analysis with other vector and raster data. Again, the management of greenness maps, similar to MODIS and rainfall estimates, is automated at FAO.

NLC users have responded very positively and favourably to the greenness maps because they are much easier to interpret than MODIS imagery and because a single map can show the status of green vegetation over time. In many countries, the greenness product has replaced MODIS. Even though greenness maps are popular, they still suffer from the inherent limitations of MODIS, specifically those related to the sensor. Ground-truthing activities are in progress to validate greenness maps in order to better understand their strengths and weaknesses.

4. Seasonal predictions

FAO DLIS also uses seasonal predictions of rainfall and temperature anomalies and forecasts up to six months in advance (Figure 5).

The aim of seasonal forecasting is to quantitatively estimate the probability distribution of the deviations of rainfall and temperature from normal. Monthly forecast maps are produced under contract for the FAO DLIS by Prescient Weather (USA). The forecasts are computed from numerical weather models of the European Center for Medium-Range Weather (ECMWF) and the U.S. National Weather Service's Climate Forecast System (CFS). Tens of cases are run to encompass the range of uncertainties and probabilities are calculated from the ensemble of individual forecasts. The maps indicate the percentage of normal rainfall that is to be expected, the probability that the rainfall will be above or below normal, the deviation from the mean temperature, and the probability that the temperature will be above or below average. The basic resolution of the maps is approximately 1.5 to 2.0 degrees latitude/longitude. The geo-referenced maps are automatically incorporated into the SWARMS GIS for analysis.

The seasonal prediction products are extremely difficult to interpret and use on a reliable basis. This is mainly due to the highly variable nature of rainfall and temperature predictions from month to month in arid and semi-arid areas. Therefore, while FAO DLIS uses this product, it is not re-disseminated to locust-affected countries because it could lead to incorrect decision-making.

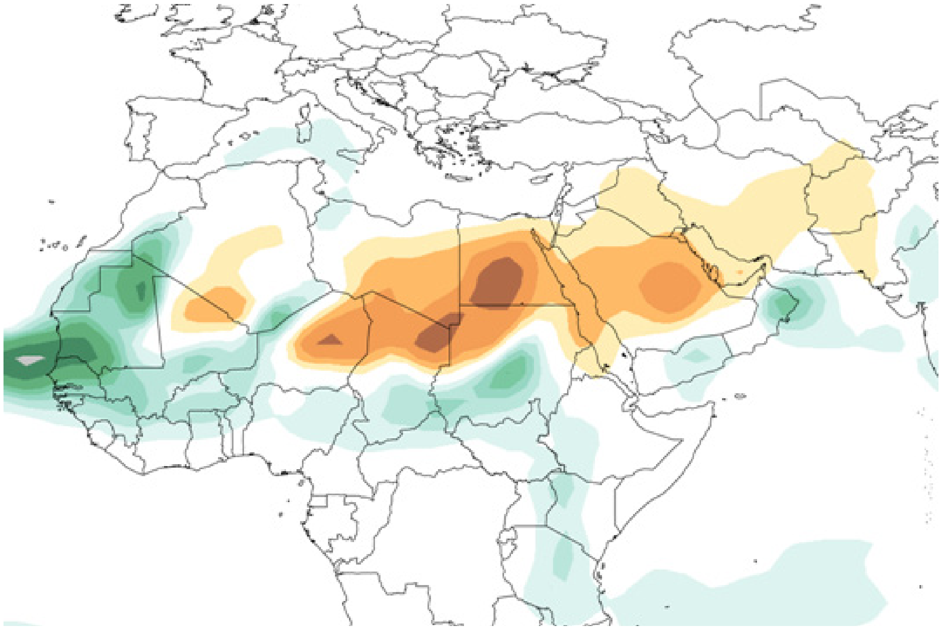

Figure 5. Seasonal predictions of rainfall anomalies up to six months in advance are incorporated into FAO DLIS locust analysis and forecasts (warmer colors indicate below-normal normal rainfall, cooler colors indicate above-normal deviations).

5. Meteorological data

FAO DLIS operates a desert locust trajectory model that estimates adult and swarm migration trajectories forward and backward in time (up to 10 days). The data to operate the model consists of temperature, pressure, wind direction, and wind-speed grids derived from ECMWF (0.25 degree square resolution at 16 atmospheric levels) and ECMWF EPS models (1.00 degree square resolution at 6 atmospheric levels) for 41 forecast periods of 6 hours for 0-240 hours. Meteo Consult (Netherlands) reformats the model-derived data and provides it every 12 hours, 365 days per year to FAO DLIS under an annual contract.

The large volume of data, approximately 200 gigabytes per year, is automatically transferred from the Meteo Consult server and managed on the FAO server. This data represents the greatest expense of any climate service data used by FAO DLIS in desert locust early warning.

FAO DLIS also uses synoptic data from national meteorological stations made available through NOAA within the framework of the World Meteorological Organization (WMO). The relevant data for the desert locust recession area are downloaded automatically, queried, and displayed within the SWARMS GIS.

A summary of the information used by FAO DLIS is as follows:

Climate services	Spatial resolution	Frequency	Provider	Access	Cost
Rainfall estimates	0.25x0.25 deg sq	daily, decadal, monthly	IRI	web interface, FTP	free
MODIS – NDVI, EVI	250m	16-day	IRI	web interface, FTP	free
Greenness map	250m	decadal	VITO	web interface, FTP	free
6 month seasonal predictions – precipitation	1.5-2.0 deg sq	monthly	Prescient Weather	web interface, FTP	contract
6 month seasonal predictions – temperature	1.5-2.0 deg sq	monthly	Prescient Weather	web interface, FTP	contract
Meteorological data – ECMWF, ECMWF EPS	0.25-1.0 deg sq	12 hourly	Meteo Consult	FTP	contract
NOAA – synoptic data	(station data)	3-24 hourly	NOAA	FTP	free
Desert locust	Area (km^2)	Countries	Population		
Recession area	16,000,000	20	1,770,000,000		
Invasion area	32,000,000	50	2,180,000,000		

Figure 6. Climate service products used by FAO DLIS for operational monitoring and early warning of global desert locust infestations.

FAO DLIS tailors information according to the potential audience: general for the public, technical for locust technicians, financial and humanitarian for donors, and simple for politicians. For example, the monthly FAO Desert Locust Bulletin is written in a way that gradually presents more and more detailed information. The first paragraph of the bulletin is a general summary; the first page is a summary for each region; the subsequent pages provide details of the situation and the forecast on a country-by-country basis. Another example is the information found on the Locust Watch home page where an update of the current situation is written in general terms with minimal technical vocabulary given that the Internet appeals to a broad audience.

The warnings, assessments and forecasts produced by FAO DLIS are used by affected countries to plan survey and control operations (the number of response teams, when/where to focus effort, etc.). They are also used by the international donor community to target assistance and especially during emergencies to determine the timing, type, urgency, and number of recipients in need of support.

Specifically, information and products provided by this climate service are used by NLCs to identify and prioritize those areas in the desert that should be checked by field teams for green vegetation and desert locust populations. In other words, rainfall estimates, MODIS imagery, and greenness maps help guide ground teams to locations where there is the highest probability of finding desert locusts. From there, decisions must be made by the NLC regarding further survey and the need for control operations. FAO DLIS products are also used to assess ecological conditions, analyze the current locust situation, and forecast locust developments. Early intervention can reduce pesticide usage and safeguard the environment and well-targeted surveys can reduce operational costs and fuel consumption. Decisions are made on a national scale by the NLCs and on a global scale by FAO DLIS. During locust emergencies, the products are also used to help determine the level of assistance that may be required in each country for control operations.

IMPLEMENTATION

PROCESSES AND MECHANISMS

STAKEHOLDER AND ISSUE IDENTIFICATION

DLIS grew out the original mandates of FAO, which were determined by the member countries of the United Nations. FAO committed to the early warning system in 1955 and assumed full operational responsibility in 1978 (from the Anti-Locust Research Centre, later the Natural Resources Institute (NRI), in the UK).

The primary users of the FAO DLIS are the NLCs, which use the early warning information to diminish the potential impact of desert locust outbreaks, upsurges, and plagues.

International donors to the FAO DLIS effort, listed above (see "target audience"), also have stake in climate information.

IRI, national meteorological services, and the NLCs of each country are involved with the FAO DLIS service as information providers. They deliver raw data to FAO, which processes the data, operates the early warning system, runs training courses, and provides technical support.

FAO also collaborates with a number of other institutions for the purposes of data collection, analysis, and dissemination. These include: NOAA/CPC, UCL, Oxford University, Pennsylvania State University, University of Edinburgh, Wageningen University, Institute of Biometeorology, National Research Council (IBIMET, Italy), national meteorological services, Inmarsat, VITO, Prescient Weather, ECMWF, the US National Weather Service, Meteo Consult, and the Group on Earth Observations.

STAKEHOLDER INVOLVEMENT

Every locust-affected country has at least one designated national Desert Locust Information Officer (DLIO) who is associated with a NLC and is responsible for collating all field data and importing it into the custom RAMSES GIS. This data is then analyzed in combination with any meteorological data that is available from IRI and national data providers.

The field data is also sent by email to FAO Headquarters, where FAO DLIS serves as the clearinghouse for all survey and control data transmitted by national locust field teams through their respective NLC. FAO DLIS examines the data using SWARMS GIS, which allows for a detailed analysis that incorporates both data received from various climate services (e.g. rainfall estimates, seasonal temperature and precipitation predictions, NOAA station data, etc.) and historical data from the 1930s to the present. This type of analysis serves as a means to assess the current locust situation and forecast the scale, timing, and location of breeding and migration.

FAO's desert locust early warning system is relatively old, dating back nearly 40 years. During this period, relevant developments in communications and technologies have been incorporated into the system. For example, field reports were initially sent by post, then by telex (1970s), fax (1988), and email (1996). Handheld global positioning systems (GPS) were introduced to locust-affected countries in the early 1990s, followed by eLocust2 in 2006. GIS applications for data management and analysis became operational at FAO DLIS in the mid 1990s, followed by user countries in the late 1990s and early 2000 (Figure 7). These technologies were introduced progressively, starting with a few key countries to demonstrate proof of concept, and then expanded to the remaining countries. FAO provided training to users and decision-makers through national and regional courses that were followed with site visits, on-the-job training, and refresher courses.

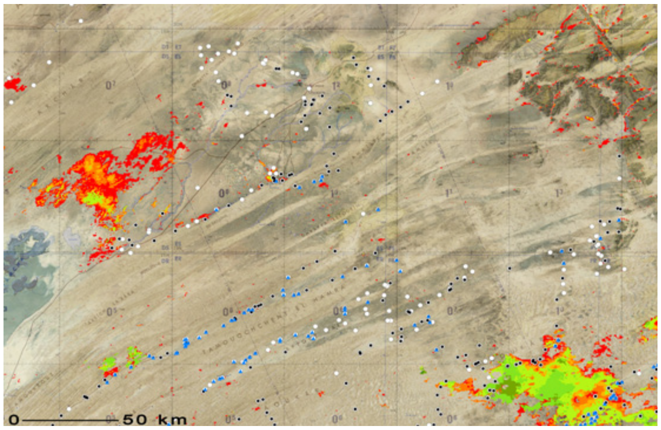

Figure 7: An example of integrating vector data (field observations of hoppers [black dots], adults [blue triangles], and no locusts [white dots]) with raster imagery (the warmer the colour, the more recent the green vegetation) in the SWARMS GIS for analysis and forecasting (example: western Mauritania, October 2010).

Rainfall products evolved from visible and infrared channels of Meteosat (from the early 1980s to the late 1990s) to rainfall estimates from 2006 onwards. Remote sensing imagery for detecting green vegetation has progressed from seven-kilometre resolution Advanced Very High Resolution Radiometer (NOAA-AVHRR) NDVI in the mid-1980s to one-kilometre resolution NOAA-AVHRR (mid-1990s), to one-kilometre resolution System for Earth Observation (SPOT, 2000), and finally to 250-metre resolution MODIS (2006). The products were introduced progressively in a similar manner as described above for new technologies.

FAO DLIS strives to collaborate with climate data providers to develop products that can be used operationally for desert locust monitoring by affected countries (the NLCs) and FAO. In these partnerships, FAO normally provides the necessary specifications and national contacts. Whenever possible, this work is undertaken at no cost to FAO, as was the case for the MODIS products and in the development of an IRI maproom for rainfall estimates. In other cases, this collaborative work is accomplished under a project framework.

From 2007 to 2011, for example, FAO DLIS was part of a World Wide Watch Project funded by the Belgian Science Policy Office under the Research Programme for Earth Observation – Support To The Exploitation And Research Of Earth Observation Data (STEREO) II. The project was part of Belgium's desire to increase its research capacity in remote sensing and develop Belgian products and services for use in the international public sector (i.e. FAO). The project is a good example of outsourcing research and product needs through cost-free collaboration with external partners. The initiative resulted in the development of meaningful tools for use by FAO DLIS and affected countries that otherwise could not be achieved in-house. This matches well with the joint project's objective to develop and deliver a set of new or more efficient global products by interacting with well-targeted end-users.

The World Wide Watch Project team consisted of two partners: the Department of Environmental Sciences and Land Use Planning/ Environmetrics and Geomatics at the Université catholique de Louvain (UCL, Louvain-le-Neuve, Belgium) and the Flemish Institute for Technological Research (VITO). UCL was responsible for all research aspects (product identification with FAO, algorithm design, prototyping, validation and bench-marking) while VITO undertook the operational components (processing, integration into the production chain, quality assurance and dissemination). The end-user (FAO) was responsible for integrating the new products into its information systems in Rome as well as into NLC systems locust-affected countries. The project was overseen by a Steering Committee composed of representatives from the European Space Agency, the EC's Joint Research Centre, and end-users (FAO DLIS).

Since 1975, FAO has issued a monthly bulletin that publishes information regarding the locust situation. Today, FAO DLIS issues the bulletin in three languages (English, French and Arabic) to locust-affected countries, the international donor community, researchers, institutes, and other interested parties. The bulletin summarizes the current locust situation and provides a six-week forecast on a per-country basis. During periods of increased locust activity, FAO DLIS also issues alerts and warnings. In the past few years, social media (Facebook[2], Twitter[3], Google+[4]) has been used increasingly by FAO DLIS to further disseminate information about the locust situation while cloud technologies are used for data storage and access. In all cases, FAO discussed the appropriateness and sustainability of these information dissemination technologies with locust-affected countries. Technologies were assimilated by FAO into international and national locust programs.

FUNDING MECHANISMS

The annual operating costs of FAO DLIS is approximately $100,000 which covers the cost of climate information, GIS support, the DLIO trainees, translations, and software licenses. Meanwhile, salaries, travel, and the secretarial costs of the Senior Locust Forecasting Officer are all covered by funds from the FAO regular programme. Additional support, provided by trust funds from FAO's three regional locust commissions, covers expenses such as transmitting eLocust2 data by satellite, conducting regional training courses, and providing computing equipment. Funding from the regional commissions is more sustainable than from other sources, as these commissions have been operational since the early 1960s.

The international donor community and, to a lesser extent, FAO, have put substantial investments specifically into the desert locust early warning system so as to develop the national capacities of locust-affected countries. These investments are delivered through FAO projects or bilaterally. Further assistance has also been provided during emergencies. This assistance often carries over after the emergency ends and is absorbed into the country's national locust programme.

Other climate information products are provided under an annual contractual arrangement between FAO and the provider. For example Meteo Consult contributes meteorological data to operate the desert locust trajectory model, and Prescient Weather contributes for the seasonal precipitation and temperature prediction products (Figure 7 above). This is not as preferable as no-cost collaboration, but there are few alternatives for value-added, commercially based data and products. This approach is not sustainable and can be easily threatened by budget cuts.

MANAGEMENT AND DECISION MAKING

The UN's Food and Agriculture Organization is the primary institution that oversees FAO DLIS.

EVALUATION

The FAO Desert Locust Control Committee (DLCC) is a body consisting of 65 member countries (locust-affected countries and donors) that advises the director general of FAO and oversees locust activities, including the services provided by FAO DLIS. As part of this management, the committee conducts an informal and qualitative evaluation of FAO DLIS's work. The DLCC meets every two years.

2 https://www.facebook.com/fao.FAO DLIS

3 https://twitter.com/faolocust/

4 https://plus.google.com/102076605231095486448/posts

A Multilateral Evaluation of the 2003-05 Desert Locust Campaign (FAO, 2006) found that:

"FAO had identified the threat at an early stage, but that its early warning and donor appeals procedures were considered satisfactory by just over half the donors. Communication during the campaign was rated as satisfactory by some 75 percent of donors and over 90 percent of the affected countries. Technical advice was rated better than satisfactory in 93 percent of cases."

The Report of the Independent External Evaluation of the Food and Agriculture (FAO, 2007 – paragraph 382) concluded that,

"FAO monitoring and early control measures had increased the intervals between locust upsurges. When these do occur, the world has been able to bring upsurges to an end more quickly with less damage to livelihoods as a result of FAO alerts, coordination and operational inputs. In other words, FAO has had very significant impact on this pest and its damage to people's livelihoods."

The IEE stated that desert locust monitoring and control is crucial for many marginal populations in Africa and Asia and for economic development in North Africa.

FAO DLIS offers regional workshops for climate information users to come together to share their experiences and learn from one another. These workshops also provide the opportunity for FAO to receive feedback from users regarding climate information products. For example, the results of a 2012 questionnaire by NLC users indicated general satisfaction with the ease and timely dissemination of the IRI rainfall estimates but some dissatisfaction was noted with MODIS delays and analysis difficulties. Ease of download, display, and analysis as well as timeliness were all considered essential elements of any climate information product.

CAPACITIES

EXISTING CAPACITIES

Affected countries themselves have limited early warning systems and generally rely on the information made available by FAO for planning. Countries also use FAO's system during actual field operations.

As such, FAO DLIS is extremely conscience of the end-users' ability to absorb climate service products and incorporate them in a meaningful way into national locust monitoring and early warning systems. FAO places significant emphasis on training and providing support to NLC users in locust-affected countries. For example, FAO DLIS has organized and conducted regional workshops for English-speaking and French-speaking national DLIOs on an annual basis since 2008. The workshops' primary objective is to strengthen national capacities and reduce reliance on external support while also providing a forum for participants to discuss their experiences, difficulties, and tips for using tools developed by FAO DLIS in their daily work. Workshops also provide the opportunity for FAO to receive feedback from users regarding their climate information products.

Most locust-affected countries have only one or two nationally designated DLIOs who are responsible for managing all of the desert locust data in their country. Some countries have up to four DLIOs. At FAO Headquarters, FAO DLIS is staffed by a permanent Senior Locust Forecasting Officer who is responsible for FAO's desert locust early warning system. He is assisted by a DLIO trainee from a locust-affected country who remains in FAO DLIS for 11 months and is then replaced by a new trainee from a different country for another 11 months. During the first half of the training period, the DLIO is given intensive instruction so that s/he can assume most of the daily responsibilities for data management in FAO DLIS during the second half of the training.

CAPACITY GAPS

The main challenge in applying climate information to the desert locust monitoring and early warning service is to identify operational and timely products that accurately indicate rainfall and green vegetation in the arid and semi-arid regions spanning from West Africa to India. These products must be of sufficient resolution to detect even small amounts of rainfall and vegetation. They must also be geo-spatial so that they can be incorporated into a GIS for analysis. Products should be easily accessible, even to those countries with very slow and erratic Internet connections. Lastly, products should adhere to the eight principles of the Global Framework on Climate Services (GFCS) listed below.

The present toolkit of climate service products does not fully meet all of the aforementioned requirements. Precipitation estimates, for example, do not accurately indicate low level, warm cloud rainfall that falls in relatively small areas along the Red Sea coastal plains during the winter. Furthermore, MODIS imagery and greenness maps suffer from omission errors due to sensor limitations and processing delays. Specifically, NLCs would also like to have accurate rainfall and wind forecasts up to six months in advance. As of now, however, seasonal predictions can be highly variable and unstable. FAO is actively investigating possibilities for improvements in all of these areas.

The prohibitive cost of meteorological data also poses a challenge and limits the ability of locust-affected countries to access and use trajectory models that predict locust migration routes, origins, and destinations.

LOOKING TOWARD THE FUTURE

GOALS

Several new products should be explored and incorporated into both the national locust early warning systems and FAO DLIS. For example, a dynamic dryness map that indicates when an area begins to dry out would aid NLCs in deciding if they should withdraw survey and control teams from the field at the end of a rainy season. This product is essentially the opposite of the dynamic greenness maps.

A soil moisture map indicating where soils are moist down to about 15 centimeters below the surface could be used in combination with a high-resolution soil map to help identify those areas suitable for egg laying. Such maps could thus be used to guide survey and control teams in the field.

These and other products should be developed if desert locust early warning and plague prevention are to become more effective and efficient in the continuing effort to improve food security and reduce hunger.

LESSONS LEARNED

A successful early warning system should consist of a network of regular surveillance, rapid data transmission and easy access, complete GIS analysis, and simple well-targeted outputs. Individuals within the system should be well trained, motivated, energetic, and curious. Teams should be well equipped. Financial support should be sustainable, for example, as an established national budget and may need to incorporate some basic incentives. Effort is required to make the work routine and teams need feedback to encourage further commitment and contribution.

Despite the advent and incorporation of new technologies into the locust early warning system, the importance of the human component and cultural sensitivities should not be underestimated. Regular contact through on-site visits must be maintained between FAO and the NLCs. NLC users need to be well trained and continually re-trained. New technologies and products must be tailored, to meet user needs and environments, gradually introduced, and continually supported. It is not sufficient to organize one training course or to deliver a new technology or product without follow up. Given that the FAO locust early warning system relies on the regular contribution of high quality spatial field data by NLCs, it is critical that NLCs have ownership of their data and receive a value added product in return for sharing. Users will not share data unless they perceive that they will benefit in some way. Furthermore, standardizing data and establishing a uniform format is essential to ensuring seamless data sharing.

The FAO locust early warning system is a good model that can be adapted for other migratory plant pests. In fact, an early warning system for Wheat Stem Rust (Ug99) was established several years ago based on FAO's locust system.

THE WAY FORWARD

The primary challenge in this case is to sustain the current desert locust early warning system. This involves the continued maintenance of a regular flow of high-quality data in the face of the global financial situation and during relatively long periods of locust inactivity.

PRINCIPLES OF THE GFCS

The FAO DLIS initiative addresses all eight principles of the GFCS.

Principle 1: **All countries will benefit, but priority shall go to building the capacity of climate-vulnerable developing countries.**

Principle 2: **The primary goal of the Framework will be to ensure greater availability of, access to, and use of climate services for all countries.**

Principle 3: **Framework activities will address three geographic domains; global, regional and national**

Principle 4: **Operational climate services will be the core element of the Framework.**

Principle 5: **Climate information is primarily an international public good provided by governments, which will have a central role in its management through the Framework.**

Principle 6: **The Framework will promote the free and open exchange of climate-relevant observational data while respecting national and international data policies.**

Principle 7: **The role of the Framework will be to facilitate and strengthen, not to duplicate.**

Principle 8: **The Framework will be built through user – provider partnerships that include all stakeholders.**

References

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