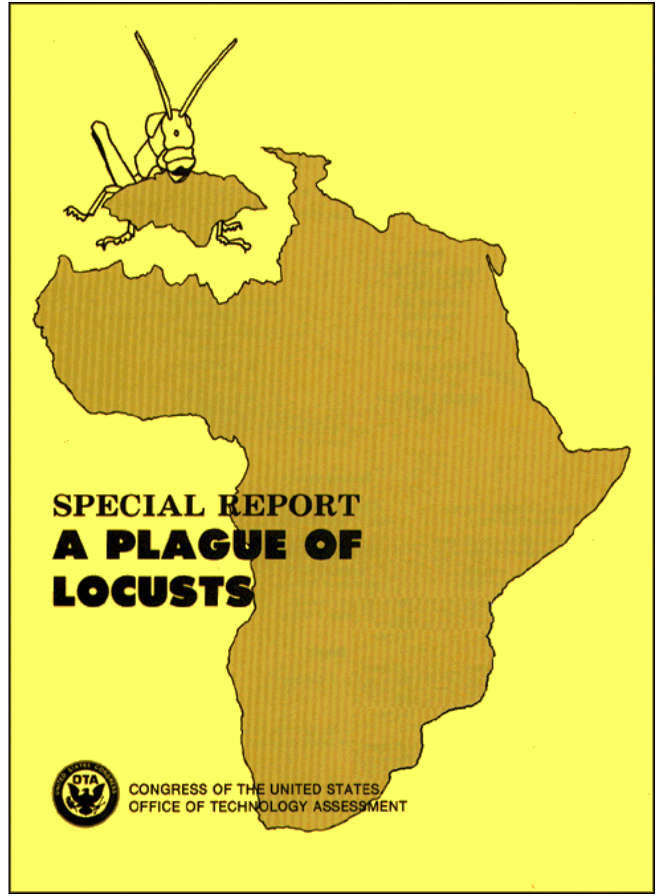
Plague of Locusts—Special Report

June 1990

OTA-F-450
NTIS order #PB90-254103



Recommended Citation:

U.S. Congress, Office of Technology Assessment, ***A Plague of Locusts—Special Report,* OTA-F-450** (Washington, DC: U.S. Government Printing Office, July 1990).

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Foreword

Widespread outbreaks of gasshoppers, then plagues of locusts, occurred in some parts of Africa from 1985 through 1989. Donors, including the United States, mobilized sizable amounts of foreign aid for disaster assistance. Congress played a role throughout the insect upsurges, appropriating special funds for disaster assistance.

Congress also had broader concerns regarding a number of environmental problems throughout Africa that seemed related to the locust and grasshopper situation. The Senate Appropriations Committee and its Subcommittee on Foreign Operations requested that OTA address a number of questions regarding how U.S. foreign aid dollars were spent during the recent plague: Was insect control timely and effective? What were the impacts on donors long-term development efforts? What should the United States do when the problem recurs?

This is OTA's fifth report on U.S. foreign aid and African agriculture and our most detailed look at one specific problem. Here, we provide background on the unusual nature of grasshopper and locust problems, examine the implications this has for the way problems are treated, then consider how U.S. contributions to the bilateral and multilateral control effort might be improved. We identify two areas of technology-integrated pest management and insect, weather, and vegetation monitoring–that could have important impacts. We include specific ways in which Congress could ensure that such improvements are made.

Like all OTA studies, this special report draws on many people's expertise. We appreciate the efforts of our workshop participants, the people who responded to our survey, and those who reviewed the two draft reports. In particular, our thanks go to staff at the United Nations Food and Agriculture Organization (FAO) and the U.S. Agency for International Development (USAID). OTA, USAID, and FAO'S analyses and policy suggestions sometimes differ. But we at OTA are grateful for the assistance these other groups provided and the thoroughness with which they reviewed our early work.

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Dedication

OTA dedicates this report to the memory of S.M. Moobola, Director, International Red Locust Control Organisation for Central and Southern Africa, in Zambia, who died in mid-1989, and to Gladys Gilbert, USAID, Addis Ababa, Ethiopia, who was killed in the 1989 plane crash of Congressman Mickey Leland's delegation. Both took part in this work. We hope that it reflects the same ideals of public service and global cooperation that they embodied.

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Executive Summary

THE BASICS

Several major species of locusts as well as significant populations of various grasshoppers threatened African simultaneously in the 1980s for the first time in 50 years. This infestation began in 1985 and 1986 after rains ended a severe, several-year drought and new, green vegetation allowed these pest species to proliferate. Several grasshopper species in the West African Sahel reached levels high enough to result in large-scale control efforts. Also, a major plague of Desert Locusts began in countries around the Red Sea, with swarms moving west across the Sahelian countries. By November, 1988, swarms of the Desert Locust extended from Mauritania and Senegal in the west to Iraq, Iran, and Kuwait in the east and some fragments of swarms reached the Caribbean.

The recent plague caught African nations and donors unprepared because the infrastructure to fight these insects had deteriorated in the decades since the last major problem. For donors such as the U.S. Agency for International Development, these insect problems caused shifts in funds, operations, and programs to cope with the apparent emergency. The Desert Locust plague ended in 1989 despite predictions that it would continue for several years But longer term issues remain (see box A). Experts differ widely in their assessment of the significance of grasshopper and locust outbreaks relative to other pest problems and national level crop damage they cause; the information base on which control decisions were made is deficient; no sound technological alternatives exist for chemical pesticides; and education and training for the next generation of experts seems inadequate.

Locusts and Grasshoppers

Some 200 grasshopper and locust species, with different food preferences and geographic distribution, are agricultural pests in Africa. A smaller number cause the majority of concern, including the Desert Locust and Senegalese Grasshopper (see figure 1). Different species can invade virtually all of the continent, as well as affect the Near East and Southwest Asia. Locust and grasshopper species, with varied biological characteristics, cause recurrent problems. Locust upsurges are usually attributable to one species in a given area and they occur episodically. Grasshopper infestations often involve a number of different species and cause agricultural damage each year. The Sahelian region is particularly vulnerable.

Locusts and some grasshoppers become a serious problem when they breed rapidly, become heavily concentrated, and undergo a biological transformation to the gregarious phase. Each insect in a gregarious group (a band of young hoppers or a swarm of adults) can eat up to its own weight per day and swarms may contain millions of insects and migrate up to 1,000 km in a week. A plague occurs when many gregarious bands and swarms occur over a large area in different regions.

Damage to crops and the other vegetation is not evenly distributed but often localized, like damage from a tornado, even during a plague. The reasons for the start of an upsurge of locusts or aggregating grasshoppers are relatively well-known-bountiful rainfall and the availability of new vegetation–although the inability to forecast weather precludes accurate prediction of insect build-up The reasons for plagues' declines are less clear. Specifically, the importance of control in declines is hotly debated.

Organizations Involved in Controlling Locusts and Grasshoppers

The U.N. Food and Agriculture Organization (FAO) has coordinated international locust control efforts since the 1950s, important because locust swarms migrate across national boundaries. African national crop protection services and regional organizations supplanted the English and French colonial locust control organizations in the 1960s. Three semiautonomous regional organizations (OCLALAV for West Africa, the Desert Locust Control Organization for East Africa, and the International Red Locust Control Organization for Central and Southern Africa) conduct survey and control efforts in most of sub-Saharan Africa, where national crop protection services are less well-developed than elsewhere. Three regional FAO commissions in Northwest Africa, the Near East, and Southwest Asia, cover areas where control is handled primarily by the national crop protection agencies; they coordinate surveys, control, training, and research.

Box A–An Open Letter to OTA's Readers: A Time for Caution

Africa recently experienced the largest simultaneous upsurges of several important locust and grasshopper pests in 50 years. Public and private donors spent approximately $275 million to control these pests in at least 23 countries from 1986 until mid-1989. Some African countries spent a significant amount of their own scarce funds as well. The U.S. Government provided some $60 million worth of aircraft, pesticides, and technical assistance (usually by Americans), in that order. Some claim this is the first time a Desert Locust plague has been stopped in its tracks and that the control program deserves full credit. They say that chemical control is virtually the only technological option against locust swarms today, and that other effective and safe control methods are at least a decade away. They seem to be right.

Yet, others contend that the weather contributed more than control to the insects' decline. They say officials should not take so much credit but perhaps more responsibility: for the mostly uncounted financial, health, and environmental costs of insecticide-based control programs; for using funds for emergency efforts that might have been better spent on long term development efforts; and for focusing on a few insects that, while highly visible, do not cause crop losses as great as some other agricultural pests. They also seem to be right.

The material in this report raises some unsettling questions about U.S. policy and the use of current technology in locust and grasshopper control programs in Africa. Some of OTA's findings are clear; others are highly qualified, reflecting lack of consensus among experts. In each instance in the chapters that follow, OTA sets out the relative degree of agreement among experts, describes which parties fall into which camps, and teases out implications of the disagreement. Such treatment has decreased but probably not eliminated the controversial nature of some of our findings and these findings are the base on which OTA's further analysis is built. Therefore, some might say OTA's report is built on a foundation of sand. OTA is inclined to state that certain U.S. policies are shaky, instead.

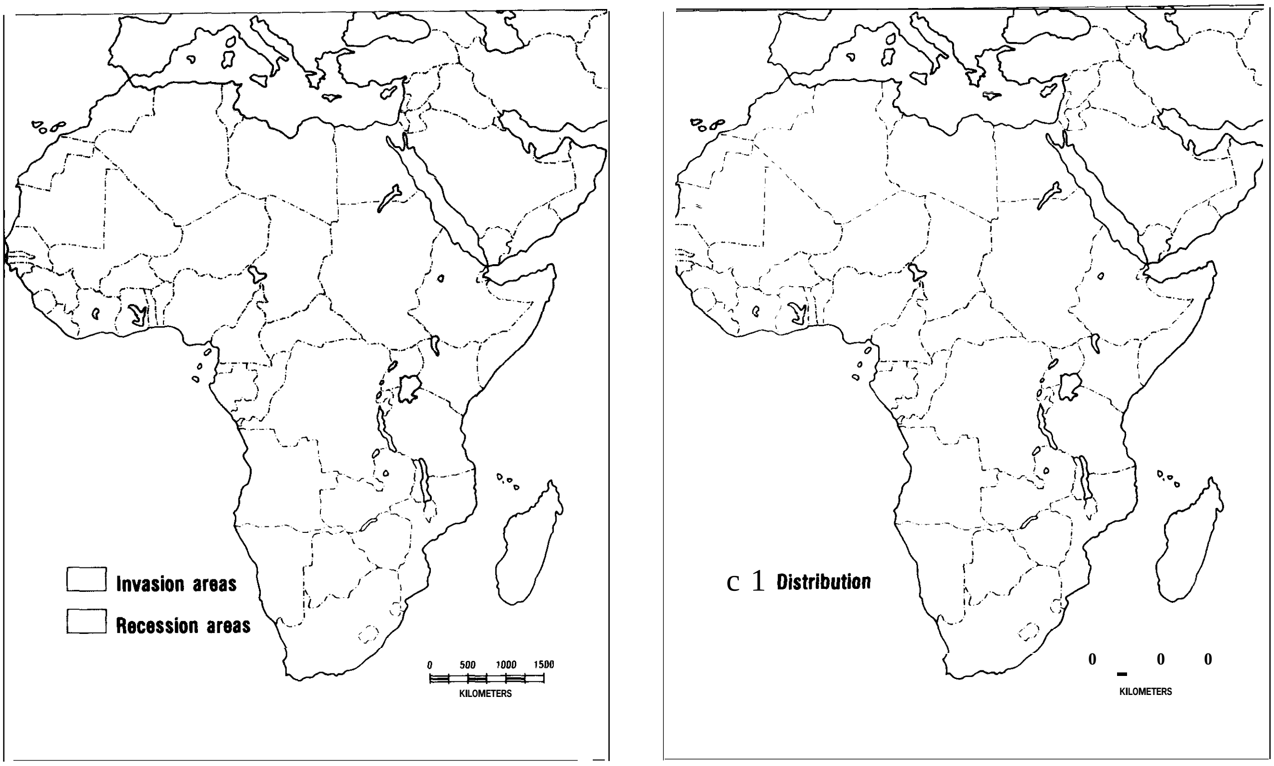
The causes for some questionable policy choices are understandable. Locusts and grasshoppers, by their ability to increase rapidly and sometimes to cause near-total destruction at localized sites, create an overwhelming and seemingly irresistible pressure for African and donor officials to take action. Such policymakers are well motivated and want to save crops and avoid famine. However, famine and national-level crop loss do not seem to be directly related to the impact of locust and grasshopper upsurges. In 1986, for example, these insects apparently caused overall crop loss of a little less than 1 percent in the 9 most affected African countries.

OTA finds that the U.S. response to the African grasshopper and locust outbreaks commonly has been based on faulty assumptions like the assumption that locust and grasshopper outbreaks lead to famine. It is time to lay better groundwork for U.S. pest management strategies in Africa. This will not be easy because of the multiple and conflicting motivations of people involved. Scientists want to be correct. Farmers and herders want to avoid risk and be productive. Policymakers want to be effective and individual nations want to preserve sovereignty. Certainly scientists' and policymakers' thoughtful assessments of grasshopper/locust situations in Africa differ markedly. Farmers' and herders' voices are not apparent in discussions of locusts and grasshoppers so their assessment of recent experience is not known, at least to OTA.

In any subject where reasonable disagreement exists, caution in making policy seems warranted. Therefore, OTA may seem to have provided more questions than answers here, finding that clear-cut options would not likely be as useful, for example, as oversight questions. Fortunately, the recent upsurges of locusts and grasshoppers seem to have passed. This is a propitious time, then, for Congress and the other concerned agencies to take the time needed to assess realistically the effects of the recent widespread spraying, and prepare for the future. For the insects WILL be back although no one can predict when, and most experts agree that improving preparedness could have solid paybacks the next time. By doing so, we might have more technological options, we might be more able to prevent problems before they grow so large as to limit policy choices, and we might be able to keep a better perspective on the overall intent–ensuring the most effective use of U.S. aid money for the development of Africa's poor.

SOURCE: Office of Technology Assessment, 1990.

Figure 1-Distribution of Two Major Species of Locust and Aggregating Grasshoppers in Africa and the Middle East



Desert Locust | **Senegalese Grasshopper**

SOURCE: TAMS Consultants, Inc. and Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment*, Main Report, contractor report prepared for the U.S. Agency for International Development, March 1989, pp. C-7, C-19.

The African national crop protection services, usually under the Ministry of Agriculture, are the major national organizations responsible for grasshopper control and they take over when problems exceed the capacity of individual farmers. They carried out ground spraying in the recent campaigns, sometimes assisted by farmer groups. Aerial spraying, often executed under regional or donor auspices in the Sahel but by national agencies in the Maghreb, was used for more extensive or remote infestations.

Donors contributed some $275 million from 1986 through mid-1989 to locust and grasshopper control, mainly in Northwest Africa and the Sahel. The United States gave $59 million, about 20 percent of the donor funds (tables 1 and 2). U.S. aid provides assistance primarily through the U.S. Agency for International Development (USAID). The Office of Foreign Disaster Assistance is responsible for short-term aid (3 to 6 months) whale regional bureaus and the Bureau for Science and Technology provide longer term aid.

As a result of donor and African countries' efforts, approximately 4.6 million ha of land in 10 Sahelian and West African countries received aerial or ground insecticide treatments in 1986 and 1987, mostly against grasshoppers. In 1988,10 million ha were sprayed in Northwest and West Africa, mostly against Desert Locusts and approximately 13 million liters of insecticides were used, mostly in Northwest Africa, at a total cost of about $100 million.

Controlling Grasshoppers and Locusts

Most traditional methods have been replaced by the use of chemical insecticides, at least in official programs. The most effective traditional

Table I-Donor Assistance to Locust and Grasshopper Control Programs, 1986-89
(U.S. dollars/calendar year)

Donors	1986	1987[a]	1988	1989 (Jan.-May)	Total
Bilateral donors:					
Algeria	50,000	146,882	180,000	0	376,882
Australia	0	0	***205,000***	0	205,000
Austria	0	0	***29,041***	0	29,041
Belgium	130,000	266,714	***500,000***	1,300,000	2,1%,714
Canada	3,014,500	2,802,238	***2,243,000***	***343,000***	8,402,738
China	500,000	*	***40,000***	120,000	660,000
Denmark	692,500	635,369	***2,813,068***	2,400,000	6,540,937
Finland	400,000	0	***208,455***	75,000	683,455
France	1,792,537	3,491,738	***6,030,127***	3,150,000	14,464,402
Germany (FR)	3,025,887	6,209,031	***11,992,000***	14,250,000	35,476,918
Greece	50,000	0	160,000	0	210,000
Indonesia	0	10,000	25,000	0	35,000
Iran	0	0	7,500	0	7,500
Israel	0	*	0	0	*
Italy	2,659,000	2,471,386	2,994,675	1,000,000	9,125,061
Japan	1,288,000	*	4,100,368	13,620,000	19,008,368
Kuwait	0	0	1,000,000	0	1,000,000
Libya	0	0	1,212,000	0	1,212,000
Luxembourg	0	**140,000**	244,000	0	384,000
Morocco	20,000	0	320,000	0	340,000
Netherlands	2,350,000	1,850,000	6,592,347	0	10,792,347
Nigeria	0	0	400,000	0	400,000
Norway	3,127,000	1,500,000	1,615,000	2,000,000	8,242,000
Portugal	0	0	606,000	0	606,000
Qatar	0	0	12,000	0	12,000
Saudi Arabia	0	0	2,860,000	0	2,860,000
Spain	62,511	0	2,440,000	0	2,502,511
Sweden	1,185,929	0	2,599,386	0	3,785,315
Switzerland	403,000	92,790	944,268	338,000	1,778,058
Thailand	11,000	0	0	0	11,000
Tunisia	0	0	90,000	0	90,000
Turkey	0	0	500,000	0	500,000
United Kingdom	1,909,183	987,687	5,800,000	***207,000***	8,903,870
USAID	9,1%,245	6,983,332	21,599,859	***12,000,000***	49,779,436
U.S.S.R.	0	*	1,376,000	0	1,376,000
Yugoslavia	64,000	0	0	0	64,000
Subtotal bilateral donors	31,931,292	27,587,167	**81,739,094**	**50,803,000**	**192,060,553**

Table l-Donor Assistance to Locust and Grasshopper Control Programs, 1986-89-Continued (U.S. dollars/calendar year) Continued

Donors	1986	1987[a]	1988	1989 (Jan.-May)	Total
Multilateral donors:					
African Development Bank	165,000	0	200,000	6,019,730	6,384,730
Banque Africaine de Developpement Africain (BADEA)	750,000	0	0	0	750,000
European Economic Community (EEC)	10,739,981	2,348,674	9,600,143	400,000	23,088,798
Islamic Development Bank	0	0	14,400,000	2,044,000	16,444,000
Organization of African Unity (OAU)	0	321,430	300,000	0	621,430
Organization of Petroleum Exporting Countries (OPEC)	300,000	0	39,000	0	339,000
UN Children's Fund (UNICEF)	86,000	*	10,000[c]	0	%,000
UN Development Program (UNDP)	1,839,000	54,000[b]	2,926,332	0	4,819,332
UN Environment Program (UNEP)	0	0	48,405	0	48,405
UN Food and Agriculture Organization (FAO)	2,601,000	20,000	4,700,000	610,000	7,931,000
UN World Food Program (WFP)	18,000	0	0	0	18,000
UN World Health Organization (wHo)	4,480	0	0	0	4,480
Subtotal multilateral donors	**16,503,461**	**2,744,104**	**32,223,880**	**9,073,730**	**60,545,175**
Non-Governmental Organizations	**1,211,460**	**133,000[c]**	**1,111,000**	**0**	**2,455,460**
Total	49.646.213	30 464 271a + 20,000,000[a] 50,464,271	115.073.974	59.876.730	255.061.188 + 20,000,000[b] 2 7 5 . -
USAID as percent of total	**18.5%**	**22.9%**	**18.7%**	20.0%	19.5%

NOTES:

"Amount unknown (1987).

'Includes only assistance to Sahelian and West African countries.

[b]Includes only assistance to two of four recipient countries.

[c]Includes only assistance from section aid to Gambia.

[d]An additional $20 million was given by donors for programs in Northwest African countries, Sudan, Ethiopia, and Yemen (Jeremy Roffey, Emergency Center for Locust Operations, FAO, personal communication, June 26, 1989).

SOURCES:

Column 1: Jeremy Roffey, "1986 Funding Chart for Grasshopper and Locust campaigns in Africa" (Emergency Centre for Locust Operations, U.N. Food and Agriculture Organization, Rome, December 1986).

Column 2: U.N. Food and Agriculture Organization, "Report of the Meeting on the Evaluation of the 1987 Grasshopper Campaign in the Sahel, Annex V (Emergency Centre for Locust Operations, Rome, December 1987).

Columns 3 and 4: U.N. Food and Agriculture Organization, "Assistance Provided to Countries and Regional Organizations," Report of the Thirtieth Session of the FAO Desert Locust Control Committee, AGP:DLCC/89/4, Rome, Italy, June 12-16, 1989.

Table 2–U.S. Assistance to Locust/Grasshopper Programs, Fiscal Years 1986-89

country	1986	1987	1988	1989	Dollars
Sahel and West Africa					
Burkina Faso	$268,800	$5&,&2	0	0	$860,532
Cameroon	200.000		0		400,000
Cape Verde	‘ O	‘ O	75,000	25,(X)8	100,000
Chad	990,841	1,254,211	1,305,730	0	3550,782
Gambia	35,000	594,898	( )[a]	25,000	654,898
Guinea Bissau	29,000	290,320	0	0	319,320
Mali	1,287,080	1,012,433	1,775,110	200,000	4,274,623
Mauritania	154,000	227,500	1,446,964	866,256	2,694,720
Niger	61,000	337,386	1,199,647	317,000	1,915,033
Sénégal	1,657,349	1,923,752	245,892	3,362,320	7,189,313
Sahel Regional	244,000	0	0	0	244,000
East and Southern Africa					
Botswana	1,183,587	0	0	0	1,183,587
Ethiopia	75,000	380,516	407,820	13,800	877,136
Sudan	1,024,948	600,000	662,415	173,713	2,461,076
Tanzania	50,000	0	0	0	50,000
Zaire	10,860	0	0	0	10,860
Zambia	100,000	0	0	0	100,000
East Africa Regional	0	0	0	0	0
Northern Africa and S.W. Asia					
Algeria	0	0	1,070,032	18,866	1,088,898
Jordan	0	0		152,600	152,600
Morocco	0	0	5,295,71!	10,308,974	15,985,203
Pakistan	0	0	0	2,000,000	2,000,000
Tunisia	0	0	1,361,447	1,410,535	2,771,982
Yemen	0	135,598	0	0	135,598
African Regional	75347	0	5,578,414	4,123,988	9,777,749
Total dollars	**$7,446,812**	**$7,548,346**	**$20,424,184**	**$22,998,052**	**$58,797,910**
Amount of total granted to FAO	**4,084,587**	**358,000**	**2,465,000**	**1,508,910**	**8,416,497**
Amount of total, OFDA funds[b,c]	**7,171,012**	**6,384,059**	**9,643,950**	**5,585,652**	**28,784,673**

NOTES:

[a] Assistance to Gambia in 1988 and some in 1989 included in amount for Senegal.

[b] U.S. assistance consists of OFDA funds, USAID mission funds, Africa or Asia/Near East Bureau regional funds, and some local currency. In FY 1988, OFDA contributed $9,643,950, the missions $4,840,600, the regional programs $6,689,656, and local currency $2,350,464, for a grand total of $23,524,670. In FY 1989, OFDA contributed $5,585,652, the missions $15,847,400, the regional programs $1,565,000 and local currency $1,850,343, for a grand total of $24,848,395. Thus, the percent of OFDA funding decreased significantly in 1988 and 1989.

[c] Information in this line from John Gelb, 1989, below.

SOURCES:

1986–John Gelb, Office of Foreign Disaster Assistance, AID, “USG Contributions to Locust/Grasshopper Threat in Africa - FY 1986 as of September 30, 1986,” n.d.

1987–Office of Foreign Disaster Assistance, “Insect Infestation,” OFDA Annual Report Fiscal Year 1987 (Washington, DC: USAID, 1988).

1988–Office of Foreign Disaster Assistance, “Insect Infestation,” OFDA Annual Report Fiscal Year 1988 (draft) (Washington, DC: USAID, 1989).

1989–John Gelb, Office of Foreign Disaster Assistance, “U.S. A.I.D. Support, Desert Locust Task Force, FY 1987-89,” dated July 22-23, 1989. Due to the decline of the locust problem in early 1989, some of the funds allocated have been reprogrammed for other crop protection activities.

method consists of driving hoppers into trenches and then burning, drowning, or crushing them. Arsenic was the first chemical used against these pests. Ground and then aerial spraying of persistent organochlorines (dieldrin and BHC) became the preferred control method in the 1950s. But dieldrin was banned, first in the United States and then Europe, in the late 1970s because of its environmental and health hazards. Fenitrothion and malathion were the major chemicals used in the recent campaign.

WHAT IS THE PROBLEM?

Most people, and many locust experts, view the recent upsurges of locusts and grasshoppers as a disaster threatening Africa's already precarious food security. Swarms put political pressure on national leaders and donors to mount aggressive, chemical control. National government and donor policies are based on the assumptions that locusts are a serious problem, that pesticides are the way to control them, and that control programs benefit low-resource farmers and herders substantially. Others disagreewith these assureptions; OTA also finds theassumptionsquestionab le. Experts differ over:

- the insects' impact on food production and whether they cause famine;
- the effectiveness and cost-efficiency of control programs based exclusively on chemical insecticides;
- insecticides' impacts on human health and safety and the environment; and
- how control should be organized and which strategies should be pursued.

Locusts and grasshoppers are relatively minor pests even during upsurges in terms of overall crop losses, although localized damage maybe devastating for short periods. Economic losses depend on which plants are affected and their age so damage is unevenly distributed among commercial and subsistence farmers and herders. The link between famine or food shortages and locusts and grasshoppers is questionable. Locusts and grasshoppers can harm national agricultural production if they devastate areas crucial to a nation's economy (as in 1954 when Desert Locusts destroyed citrus trees in Morocco's Seuss Valley). This type of damage did not occur in the recent plague, however. Damage was less than drought would produce, and losses were localized, with the aggregate level of reduction in 1986 in the nine countries most affected by grasshoppers down only about 1.0 percent in weight and 1.5 percent in value, according to FAO and USAID estimates.

The Effectiveness of Control

The efficacy, efficiency, and equitability of locust and grasshopper control programs are undocumented. While insecticides can protect standing crops, their ability to end or prevent plagues is not clear. Nor have the economic benefits of crop protection been demonstrated. Experts' views on reasons for the decline of plagues range from "entirely due to weather" to "control programs were the major factors curtailing the plague." Key data for resolving these differences of opinion are lacking. It seems that, in some places, at certain times, properly administered control can help interrupt the sequence of events that could contribute to an upsurge's spread. While climate is the dominant factor, it seems that chemical control can play an important role, at least on the national scale.

Various insecticides have different relative effectiveness based on ingredients and formulations. A number were used in the recent campaigns, often in ways that reduced or negated their effectiveness, e.g., when temperatures and wind speeds were beyond recommended ranges, after insects had laid eggs, or when some areas were unnecessarily resprayed. Chlorinated hydrocarbons—dieldrin, lindane, and BHC—were eliminated from U.S.-supported efforts after USAID was sued by environmental groups in 1975. FAO, however, advocates continued use of dieldrin, claiming it is effective, cost-effective, and not harmful. Some European donors still supply lindane. All three were used in the most recent African locust and grasshopper campaign, although in small amounts, and unused stocks remain. The insecticides with USAID's qualified approval for use against grasshoppers and locusts changes over time. That list is not totally congruent with insecticides registered for use against grasshoppers and locusts in the United States by the U.S. Environmental Protection Agency (EPA). Reliable field measurements of spraying's impact on insects and nontarget organisms have not been made.

The recent control efforts were plagued by problems. Opportunities to spray hopper bands, when the insects were more concentrated, were missed because of the:

- inaccessibility of breeding areas;
- lack of vehicles, communication equipment, and trained personnel;
- governments' not allowing cross-border survey or spray operations;
- crop protection services' priority to protect cropland; and
- wars and civil strife.

Additional problems existed in the earliest part of the campaign: lack of preparedness of staff, impassability of roads in the rainy season, donors' diverse policies, and late arrival of equipment and pesticides.

Costs of the control programs in Africa were high, especially because chemicals had to be imported and transportation costs were high–from $15 to $30 per hectare in 1986, compared to $5.50 to $9.00 per hectare for grasshopper control in the United States. The cost-effectiveness of control has not been demonstrated. Some evidence exists that in 1986 the value of production saved in the nine most affected countries did not equal or exceed the costs of control: a total of $40 million for control to save $46 million of production. The data on which this conclusion is based are few, however, partly due to donors lack of effort in collecting them and partly due to problems inherent in the effort.

Impacts on Health and the Environment

Safe and environmentally sound use of insecticides was not ensured during the recent locust and grasshopper campaigns. Application, storage, and disposal were not monitored and the cumulative effects of chemicals used in various agricultural and health programs were not taken into account. Case reports exist of toxic human exposure, especially to those who handled insecticides. Insufficient attention was paid to the effects of locust and grasshopper spraying on scarce food and water supplies. Empty pesticide containers have been used to store food and water.

Various pesticides used in the campaign are known to have harmful effects on nontarget organisms (e.g., fenitrothion to birds and fish and carbaryl to honeybees) and some of these occurred. Honeybee colonies were killed in Tunisia and 30 sheep died after grazing on pesticide-contaminated land. Insecticide residues were found in the soil in Mali and Morocco. Storage and disposal of surplus insecticides and containers is recognized as a major problem by African governments, donors, and FAO. Problems such as inadequate packaging and labeling have resulted in contamination and loss of effectiveness.

Institutional and Political Aspects of Control

Most African national and regional agencies and donor institutions are not equipped to deal with locusts and grasshoppers on a long-term basis. Commonly, development goals are sacrificed in favor of emergency management. In Africa, civil strife and long-standing border disputes constrained access to some of the most important areas for conducting insect surveys and control.

The shortcomings of Chad's national crop protection service in dealing with locust and grasshopper programs were typical: imprecise data on pests, vehicle breakdown, poor training, shortage of survey materials, inadequate preparations before the rainy season, inaccurate treatment figures, and no monitoring of adverse effects. Donor organizations exhibited a different set of shortcomings: organizational shifts and redirection of funds from development to crisis management, and lack of experts experienced with technical aspects of the program and with African situations.

STRATEGIES FOR THE FUTURE

USAID made commendable attempts to: 1) coordinate its efforts with U.S. agencies; foreign donors and African officials; 2) provide training to

Africans and its own personnel; and 3) stress sound selection, storage, application, and disposal of insecticides.

The Office of Foreign Disaster Assistance (OFDA) Desert Locust Task Force was the focal point for coordination. It held weekly meetings, bringing together experts from the U.S. Department of Agriculture's Agricultural Plant Health and Inspection Service and the Forest Service, the EPA, and the U.S. Geological Survey (USGS). Also, the Task Force reviewed its work annually and prepared a helpful ***Locust/Grasshopper Management Operations Guidebook.*** USAID held 10 training workshops and funded additional training by FAO and a regional organization.

USAID advocated use of less toxic insecticides, a ban on dieldrin, and improved disposal of containers and surplus stocks. Also, USAID supplied protective clothing for pesticide applicators and tested applicators' cholinesterase levels in one country. USAID clearly prevailed in reducing dieldrin's use. USAID attempted to make control more efficient and less costly by pre-positioning chemicals in Europe and using remote sensing (greenness maps) to identify areas for ground surveys.

How To Do Better Next Time

Overall, the results of locust and grasshopper control were disappointing. Donors cannot afford to fund expensive control campaigns without addressing fundamental questions regarding goals and implementation. Now that the insects are in recession, it is time to find methods that contribute to development, to redouble preventive efforts, to decide what actions will be most effective during the next upsurge. OTA finds that four areas deserve special attention. Each has important implications for the organization of African regional and national efforts and for donor funding.

The Feasibility and Price of Prevention

FAO and USAID maintain that the plague prevention strategy that evolved in the 1960s surveys in seasonal breeding grounds and controlling populations as they become gregarious there) could prevent plagues if properly applied. But this depends on effective monitoring and control on a continuous basis, and that is costly. Also, effective spraying is difficult in actuality, partly due to factors beyond the control of donors or governments (civil wars, weather). FAO proposes a major preventive effort in the next 5 years. It seems that such a preventive strategy would be *less expensive* than widespread control but this is undocumented so far. Crisis management mobilizes resources and attention more effectively than preventive approaches to chronic or slow-onset problems, however.

Integrating Emergency Control Programs With Long-Term Development

Far more attention was given to emergency assistance than to other efforts, including preventing insect problems from developing and identifying alternative controls in the recent campaign. For example, nearly all U.S. funds for locust and grasshopper programs in fiscal year 1986 and 1987 were OFDA funds and 58 percent of USAID's major longer term grasshopper and locust project's funds were allocated to emergency assistance for fiscal years 1988 through 1990. Respondents to OTA'S survey agreed that crisis management was the major type of activity undertaken in the recent campaign and most advocated an increase in preventive measures and specific types of relief and rehabilitation.

Individual or Multipest Strategies

Sustainable protection of crops and livestock requires comprehensive, multipest management solutions. Management of all grasshoppers and locusts, however, may not be able to be integrated into single organimations. Some species, e.g., the Senegalese Grasshopper and African Migratory Locust, can be controlled by national crop protection services in programs integrated with efforts against other pests. Others, e.g., the Desert Locust, might be more effectively dealt with regionally as a single species because it breeds in remote areas and migrates among countries.

When and Where Control Efforts Should Be Mounted

During the recent campaigns, vast areas were sprayed with insecticides. The high cost of these efforts, including the less documented environmental costs, require a reexamination of where and when spraying should be done when outbreaks occur. The relative merits of early treatment (e.g., FAO's "strate "c control progrm" aimed at hopper bands inr reeding areas) v. later treatment (e.g., when swarms or bads actually threaten crops) arehotlydebated. The former maybe more costly financially, and the latter politically. Generally, a need exists to improve the precision and accuracy of control efforts. USAID would have to revise its strategy of controlling swarms wherever they occur in order to do this.

What Control To Use: The Role of Technology

Today, widespread insecticide spraying is the predominant technology used against grasshoppers and locusts. Three areas of technolgy seem promising for the future: integrated pest management (IPM), alternative controls, and monitoring insects, weather, and vegetation.

Major elements of 1PM apply during locust and grasshopper upsurges: optimization of control, use of multiple control tactics, keeping pest damage below economic injry level to maintain stable crop production, and minimization of insecticides' hazards. These were not followed in the recent control efforts despite 1PM being USAID's stated policy. This was partly due to lack of technolo and partly due to the poor decision-making and performance by donors and African agencies. Today, biological control, cultural practices, and other nonchemical components of 1PM cannot provide the high level of control needed to stop gregarious swarms. In the future, these methods might, however, contribute significantly when used together or at early states of an infestation. Research on alternatives and improved use of pesticides can be done now and, in fact, must be supported now if alternatives are to be available for future locust and grasshopper upsurges. Experts estimate that it maybe 8 to 10 years or longer before alternatives to insecticides are available for large-scale use.

Biological control (the use or encouragement of natural enemies for the reduction of pests) is one potential component of 1PM. Microbial control methods now being researched include *Nosema* (a protozoa) and viruses that could be incorporated with microbial pesticides. Biorational control methods also include botanical pesticides and pheromone traps, other potential alternatives to synthetic chemical insecticides. The chemicals contained in the neem tree have received attention as a botanical insecticide with antifeedant properties.

Monitoring insects, weather, and vegetation can be done from the ground or from the air. Generally, ground momtoring technologies are adequate, but jurisdictional questions, remoteness of breeding areas, and lack of resources in crop protection services cause them to be used ineffectively. Current technologies for aerial monitoring tend to be imprecise and their results delivered too late. An array of remote sensing satellites has developed. USAID and FAO fund important remote sensing-based early warning systems for locust and grasshopper monitoring. USAID sponsors greenness maps to help guide ground surveys. In 1987, USGS began using U.S. National Oceanic and Atmospheric Administration (NOAA) satellite data to create time-series maps of vegetation changes. FAO began its ARTEMIS (African Real Time Environmental Modeling Using Imaging Satellites) program in 1988 (using Meteosat, the European Space Agency satellite, and NOAA data) to forecast rainfall and monitor changes in vegetation. Currently, remote sensing for early warning of grasshopper and locust upsurges is not considered fully operational.

POLICY OPTIONS FOR CONGRESS AND THE EXECUTIVE BRANCH

Congress and the Executive Branch can take a number of actions to improve pest management in developing countries in general and locust and grasshopper control in particular. Congressional micromanagement of the U.S. foreign aid program is neither desirable, effective, nor OTA's intent, but USAID's inaction or ineffectiveness has left a policy vacuum that Congress may need to fill. Mostly, the need exists for careful congressional oversight of USAID programs–rather than new authorizing legislation–that helps U.S. officials decrease the uncertainty surrounding grasshopper and locust problems (box B).

Box B--High Priority Policy Options for Congress

Chapter 4 sets out detailed oversight questions and policy options and their rationale (see boxes 4-A through 4-D). The following high priority areas are drawn from more extensive set.

Revising USAID Strategy

Oversight Questions:
- justification for widespread pesticide spraying from 1986 to 1989
- revised plans for "next time"

Congressional Options:
- revising USAID's Locust/Grasshopper Strategy Paper for Africa
- reviewing USAID's pest management planning
- implementing the Programmatic Environmental Assessment's recommendations

Implementing Integrated Pest Management (IPM)

Oversight Questions:
- scenarios for different Agency responses
- research on alternative controls
- implementation of IPM
- increased USAID technical capacity
- support for IPM extension and training in Africa

Congressional Options:
- completing USAID's Pest Management Sector Review
- establishing a Pest Management Task Force

Using Pesticides Judiciously

Oversight Questions:
- storage and disposal problems
- more selective and efficient insecticide use
- combined impact of spraying for health and agriculture

Congressional Options:
- specifying more selective, effective, and safe insecticide use

Coordination and Support for African, U.N. and Regional Organizations

Oversight Questions:
- the impact of policy reform
- the benefits of "greenness" maps
- coordination among donors and African countries

Congressional Options:
- setting priorities for various groups' support
- identifying how Congress impedes USAID's impact

SOURCE: Office of Technology Assessment, 1990.

OTA's work builds on several recent studies on pesticide use in developing countries:

- *Opportunities to Assist Developing Countries in the Proper Use of Agricultural and Industrial Chemical (1988, 22);*
- *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment (1989, 95); and*
- *African Emergency Locust/Grasshopper Assistance Project Mid-term Evaluation (1989, 99)*

At least two of these three reports stress: a) the need for increased emphasis on integrated pest management, b) improved use of pesticides, c) assessing the cumulative impacts of control, d) the need for training and technical assistance on topics such as the safe and sound pesticide use, storage, and disposal, e) additional research on alternate control methods, and f) addressing institutional factors that hamper efforts, including needed management changes within USAID.

Revising USAID's Strategy

USAID's approach would require significant changes if the United States wants to play a leadership role in developing sustainable pest management strategies for Africa: giving higher priority to IPM; building in-house scientific capacity to improve its capacity to use pesticides judiciously; and improving internal, interagency, and international coordination as well as finding improved means to support various other groups involved in pest management.

USAID currently has enough information to revise the Africa Bureau's 1987 ***Locust/Grasshopper Strategy Paper*** and to ensure that the ***Locust/Grasshopper Management Operations Guidebook*** conforms to these revisions and that the recommendations of USAID's Programmatic Environmental Assessments are implemented. OTA finds that Congress might encourage USAID to form a broad Pest Management Task Force to oversee implementation of these recommendations and coordinate the U.S. response to various worldwide plant protection initiatives. Also, the USAID Task Force might commission an external group to evaluate the 1986 through 1989 control programs in Africa. The Task Force might also designate a standing subcommittee on research to solicit, evaluate, and fund IPM research proposals related to locust and grasshopper control.

Implementing Integrated Pest Management

More fully using IPM in grasshopper and locust programs will require a sizable investment in research, training of Africans, and improved technical capacity among USAID staff. Since IPM is a multipronged systems approach, it will require renewed efforts at coordination and drawing together information from a variety of sources: U.S. universities, U.S. and African government agencies, and other donors.

The United States has important capabilities to contribute to improved pest management strategies, but this approach is not well-understood nor fully implemented by those who led the recent grasshopper and locust campaigns. A clear need exists for training African farmers, extension agents, and national crop protection services in IPM as well as supporting several types of research.

Using Pesticides Judiciously

USAID needs to examine carefully its research, evaluations, and technical assistance regarding insecticides and then incorporate results so that chemicals are used more selectively. Training in safe and effective pesticide use should be a key component of donor crop protection efforts. Donor coordination will be essential if U.S. policies are to have the greatest impact.

Currently, controversy and confusion reign on such issues as the best insecticides to use, the threshold at which to mount control, and the habitats most vulnerable to hazards. USAID could improve this situation by sponsoring further training at all levels, making one person responsible for providing USAID missions with insecticide-related information, preparing and updating country supplemental environmental assessments, and implementing its own staff's suggestions from the last campaign. In some areas, USAID cannot implement measures to improve pesticide use without congressional action. Granting waivers to certain requirements may help bring about more efficient control.

U.S. Coordination and Support for African, U.N., and Regional Organizations

Many African national crop protection services are poorly equipped to takeover a large part of locust and grasshopper monitoring and control or to develop integrated pest management strategies. Better coordinated regional approaches are needed but support for building individual crop protection services must be a significant part of donor assistance.

Regional groups have a distinct advantage in dealing with regional problems such as migratory pests like grasshoppers and locusts. African regional organizations must continue improving their management and financial support to reach their potential, however. FAO can lead in compiling data, forecasting insect upsurges, and sponsoring meetings; the international agricultural research organizations in Africa can develop alternative control methods. All of these, however, need to integrate their work better with African national agencies.

Local groups' participation in locust and grasshopper control has significant advantages. Their participation can be encouraged via the involvement of African nongovernmental organizations and donors' support for certain types of training, technical assistance, and pilot projects on extension and applied research.

Funding Implications

Some adjustments of U.S. bilateral and multilateral funding maybe necessary to ensure that the most effective pest management is undertaken. Some of monies needed to support improvements in USAID's grasshopper and locust work may come from internal shifts of funds because the Agency is no longer funding massive control efforts. Congress may want to encourage USAID to allocate more of its existing agricultural funds to pest management generally and 1PM specifically. Pest management received a declining share of the Bureau for Science and Technology's agricultural budget in recent years. This trend, coupled with reduced USAID funding to agriculture in general, means that few U.S. development assistance funds are being spent on long term pest management.

Congress replaced USAID's functional accounts with the Development Fund for Africa in 1988 to provide USAID with increased flexibility and to make funding more efficient. Congress could evaluate the impact of the Development Fund. Early indications are that agricultural funding decreased relative to other sectors as a result and pressure to fund activities that seem to have quick, visible results increased. If so, the Development Fund for Africa may neither be achieving its goals, nor be able to serve as a model for other programs.

There is no doubt that some new efforts would require new appropriations. What is not clear is how much these efforts would cost. Implementing 1PM for locusts, grasshoppers, and other pests would require funds for planning, training, research, coordination, and further preventive work such as insect monitoring and forecasting. USAID's planning for follow-on work needs to estimate such costs and present its conclusions to Congress. Certainly some improvements can be made by supplying inexpensive equipment to African organizations, e.g., fax machines, radios, spare parts. Other items, such as satellite receiving stations and major research programs, will be far more costly.

CONCLUSION

Few would argue that the United States has an obligation to assist disaster victims around the world. In some ways, the U.S. response to the 1986 through 1989 locust and grasshopper problems in Africa modeled effective disaster aid: large amounts of resources were mobilized. OTA'S research, however, uncovered distressing questions about whether locusts and grasshoppers constitute a national and international disaster and also whether the U.S. response to the problem was appropriate. It seems that pressure to take action, some coming from Congress, was overwhelming, and the scientific information that could have led to a more suitable approach was misunderstood or overlooked.

U.S. policy takes that road at its peril: massive insecticide spraying in a crisis atmosphere is costly in dollar terms; it tends to be inefficient in the short-term, ineffective in the medium-term, and misses the roots of problems in the long-term; and the potential health and environmental damage can be high. The alternative path is not readily apparent, however. Africa's pest problems are significant, the solutions are uncertain, and alternatives to chemical control are mostly unavailable. Starting down a different route now is likely to have long term benefits although the results of taking a new direction are likely to be less visible, less dramatic, and perhaps less satisfying for donors in the short-term than spraying millions of hectares with insecticides.

Chapter 1

The Basics

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Chapter 1

The Basics

SETTING THE STAGE

In the late 1980s, several major species of locusts as well as significant populations of various grasshoppers simultaneously threatened Africa for the first time in 50 years (93). This infestation began in 1985 through 1986 after rains ended a severe, several-year drought and new, green vegetation allowed these pest species to proliferate.

Several grasshopper species in the West African Sahel reached levels high enough to result in large-scale control efforts from 1985 to 1989. Also, a major plague of Desert Locusts began in countries around the Red Sea, with swarms moving west across the Sahelian (see app. A) countries. By November 1988, swarms of the Desert Locust extended from Mauritania and Senegal in the west to Iraq, Iran, and Kuwait in the east, and some fragments of swarms even reached the Caribbean.

The last widespread Desert Locust plague extended from 1949 to 1%3. Following that plague, the infrastructure to fight locusts and grasshoppers deteriorated, and the recent plague caught Africa unprepared and highly vulnerable. For donors, in-including the U.S. Agency for International Development (USAID), the Desert Locust plague, along with other locust and grasshopper problems, caused shifts in funds, operations, and programs to cope with the apparent emergency.

Despite earlier forecasts that the Desert Locust plague might continue for several more years, in April 1989 the United Nations Food and Agriculture Organization (FAO) announced that the plague had dissipated (105). But longer-term issues remain. For example, experts differ widely in their assessment of the significance of locust and grasshopper outbreaks relative to other pest problems and in terms of the crop damage they cause on a national level; the information base on which major control decisions were based seems deficient; no sound technological alternatives exist for chemical pesticides; and education and training for the next generation of experts to deal with future plagues seems inadequate.

In this study (box 1-A), OTA examines what happened during the 1986 to 1989 plague years and considers the implications of the longer-term issues. The major species of locusts and related aggregating grasshoppers in Africa and the Middle East (box 1-B) are the focus. From 1986 to 1989, most international control efforts in Africa were directed at the Desert Locust and the Senegalese Grasshopper, so most examples in this report deal with these two species.

LOCUSTS AND GRASSHOPPERS

Locusts and aggregating grasshoppers have fascinated biologists and caused farmers anxiety for centuries because of their unusual behavior. This section details the insects' biology and behavior. For readers with less need for detailed knowledge, the following information is critical to understanding later sections of this report and to making informed policy choices:

- Different locust and grasshopper species can be difficult to identify, yet they have distinct biologies that require different control strategies.

- Each insect can eat its own weight in vegetation each day. Damage mainly depends on the number of insects, how long they stay in a given area, which plants they eat (non-crop, commercial crop, subsistence crop) and the plants' stage of development

- When crowded (by breeding or congregating in moist places) these insects undergo a change–from living as scattered, sedentary individuals to becoming cohesive, gregarious bands of hoppers or highly mobile adult swarms. Swarms can migrate hundreds of miles in a few weeks.

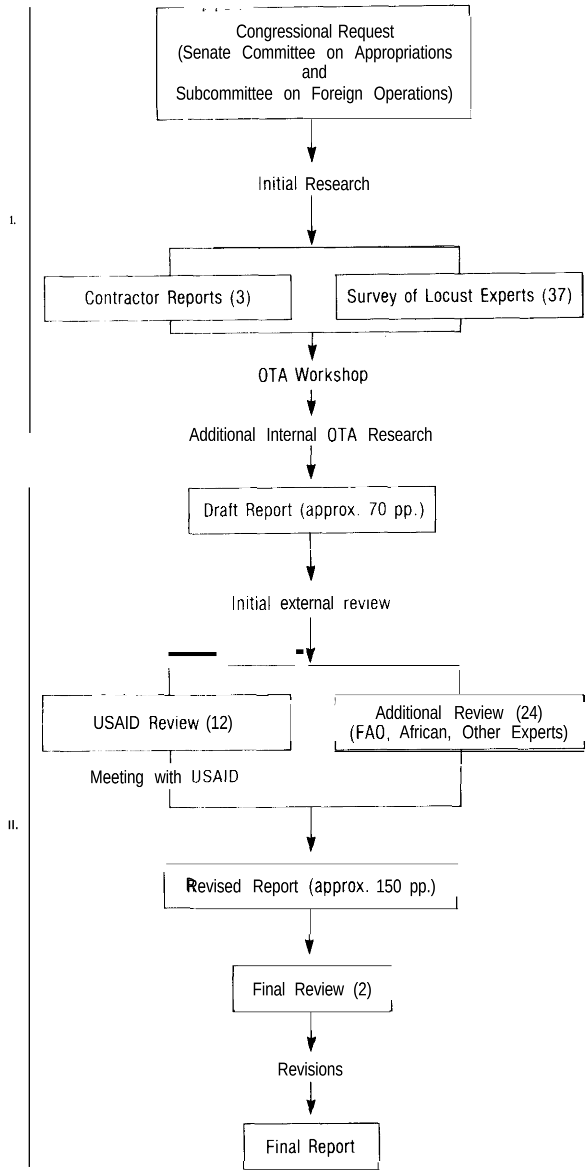
- Locusts and grasshoppers' life cycles have three stages: eggs, hoppers, and adults. Gregarious insects are most concentrated and vulnerable to control during the second stage because hoppers cannot fly.

Box 1-A–Methods of This OTA Study

The process for this study falls into two broad phases: research and synthesis (I), then writing, review, and revision (II). In the first phase, three expert contractors examined: 1) the pest situation, control strategies, and institutional aspects in both the mid-1980s and in their historical context; 2) the role of climate in pest upsurges and declines; and 3) the ethical issues involved in control campaigns (app. B). In December 1988, OTA conducted a survey (app. C) of some 100 locust experts and officials representing the range of national, regional, and international organizations involved in locust and grasshopper control and research. The survey's objective was to assess current and past infestation trends, crop losses, control efforts, and needs for future control efforts. Twenty-six people responded in Africa, the Middle East, Europe, and Canada; 11 USAID staff completed the same form (app. D).

OTA began to synthesize the findings of the expert papers and the survey results at an OTA workshop. This meeting also identified major issues, additional data needed, and preliminary policy options. OTA prepared a draft report after conducting further interviews and reviewing more publications on these topics. This draft was reviewed by representatives of USAID, FAO, African national and regional organizations, and other experts from the United States, United Kingdom, and Africa (app. E). Also, USAID staff in Washington met with OTA in addition to providing extensive written materials. OTA's report was revised substantially following this review process. The revised draft was then reviewed a second time by one of the original three contractors and FAO. This final version includes revisions based on that review as well as additional information gathered by OTA independent of the review process.

Flowchart of Study Methods



Box 1-B–Major Species of Locusts and Related Aggregating Grasshoppers in Africa and the Middle East

Locusts

- Desert Locust, *Schistocerca gregaria:* This species is potentially the most dangerous of the locust pests because of its ability to swarm rapidly across great distances. The pest has two to five generations per year.

- African Migratory Locust, *Locusta migratoria migratorioides:* This species also may swarm over large areas. During plagues, the pest may invade nearly all of sub-Saharan Africa. The outbreak areas from which swarms arise are associated with extensive and seasonally flooded grass plains along the middle Niger River, the south-southeast Lake Chad Basin, and the Blue Nile Basin of Sudan. The pest has two to four generations per year.

- Red Locust, *Nomadacris septemfasciata:* This species, with only one generation per year, occurs in Eastern and Southern Africa. During outbreaks, it may invade nearly all of Africa south of the Equator.

- Brown Locust, *Locustana pardalina:* This species is primarily found in South Africa and southern Namibia. However, swarms may invade surrounding countries in southern Africa. The pest has two to four generations per year.

- Moroccan Locust, *Dociostaurus maroccanus*: This species, with only one generation per year, is found in arid areas of North Africa. During outbreaks, it may invade areas along a belt extending from Morocco in the west to the Near East and Soviet Central Asia.

- Tree Locust, *Anacridium melanorhodon:* During outbreaks, this species may infest an area south of the Sahara that extends from Senegal in the west to Somalia, Tanzania, and Saudi Arabia in the east. However, it is normally a problem only in Sudan where it defoliates the gum arabic tree *(Acacia senegal)*. The species has one generation per year.

Aggregating Grasshoppers

- Senegalese Grasshopper, *Oedaleus senegalensis:* This species occurs in a band across Africa north of the Equator (but also reaching south in Tanzania), the Middle East, and southwest Asia. The pest has two to four generations per year.

- Sudan Plague Locust, *Aiolopus simulatrix:* This species extends from Sahel to Sudan and Egypt, southwest Asia to Bangladesh, and north to the Tadzhik Republic of the U.S.S.R. The populations are greatest in the Nile Valley, where this species is regarded as the most serious grasshopper pest. The pest can breed continuously.

- Variegated Grasshopper, *Zonocerus variegatus:* This species primarily affects forested areas of West Africa but may also extend into the Sudan and eastern Africa. It is primarily a problem in clearings of forested areas but also may be a problem in savanna areas. The pest has one generation per year.

SOURCES: Adapted by OTA from: Anti-Locust Research Centre, *Anti-Locust Handbook* (London, 1966); Dale G. Bottrell, "Locusts and Grasshoppers in Africa and the Middle East," contractor report prepared for the Office of Technology Assessment, Washington, DC, January 1989; TAMS Consultants and Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment*, Main Report, contractor report prepared for the U.S. Agency for International Development, March 1989; and B.P. Uvarov, *Grasshoppers and Locusts-A Handbook of General Acridology*, vol. 2 (London: Centre for Overseas Pest Research, 1977).

. Weather conditions affect insect behavior. Outbreaks occur after rainfall. Predominant reasons for declines also relate to weather–unfavorable breeding conditions (insufficient moisture, vegetation or low temperature) or wind patterns.

Definitions

Locusts belong to a large group of insects commonly called grasshoppers-insects recognized by powerful hind legs adapted for jumping–in the insect order Orthoptera. Technically, grasshoppers and locusts belong to the superfamily Acridoidea within that order. Therefore, they are close biological relatives.

Many scientists distinguish locusts from grasshoppers based on locusts ability to form dense groups comprised of large numbers of insects. In some cases this distinction is not clear because “aggregating” grasshoppers can behave similarly. Thus, the terms “locust” and “grasshopper” are sometimes ambiguous.

Also, the term “locust” is used nontechnically. In the United States, for example, cicadas-a different type ofinsectintheorder Homoptera-are sometimes called “locusts.” Different kinds of cicadas occur in large numbers at regular 13- and 17-year intervals. Unlike locusts, periodical cicadas do little damage to vegetation. People who have experienced their dense hatching, however, know something of what locust outbreaks are like. “bust”, in French, is "criquet," but theinsectsAmericans call crickets also differ from locusts andgrsshoppers although the three insect types sharethe same scientific order.

At least 1,500 species of grasshopers and locusts exist in Africa, with a wide spectrum of characteristics. Some 200 species have been reported as pests. Accurate scientific identification, often essential to assessing the magnitude of a pest problem and selecting suitable control methods, can be difficult.

Life Cycles: Eggs, Hoppers, and Adults

The life cycle of all species of locusts and grasshoppers consists of three stages: eggs, hoppers, and adults. Usually eggs occur in frethy cylindrical pods deposited at shallow depths in moist ground. Eggs hatch into hoppers primarily during the rainy season after an incubation period affected by temperature. Hoppers periodically “molt,” or cast off their skins, as they grow. Usually the insects molt five times, with the growth stages between each known as "instars." After the last molt, the insects are considered “fledglings,” or immature adults, but have developed wings strong enough to fly (figure l-l). Desert Locusts live from 2.5 to 5 months (93) and, under optimal environmental renditions, populations probably can multiply 10 times in each generation (71).

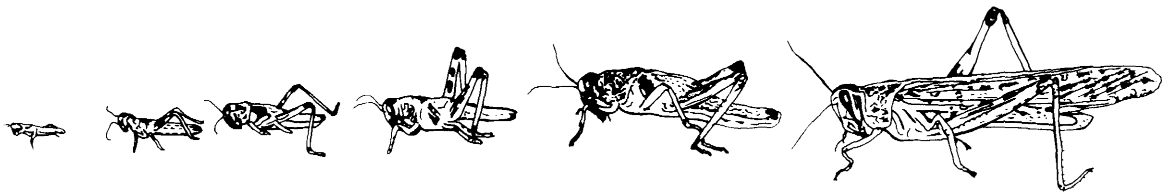
Various grasshopper and locust species differ in important ways, such as the length of time eggs can survive without rain and the insects’ vulnerability to natural enemies (predators, parasites, and pathogens). Desert Locust eggs are viable for up to 10 to 12 weeks in soil that remains sufficiently moist (118). On the other hand, Senegalese Grasshopper eggs can survive in dry soil for several years and hatch when rains come (55). Grasshopper often fall prey to natural enemies (99), but usually natural enemies only are significant sources of mortality for Desert Locusts when populations are in decline for other reasons (93). Weather, however, is the most important natural cause of Desert Locust mortality.

Behavior: Solitary and Gregarious Insects

Behavior patterns principally distinguish locusts from other grasshoppers. Locusts behave as “typical” grasshoppers and live as solitary individuals when their populations are small. However, when locusts occur inlargenumbers andhighdensity theyundergo a transformation to a gregarious phase, and move together in dense groups. Gregarious locusts are called swarms when composed of adults, and bands when composed of young hoppers. A swarm of adult Desert Locusts may contain 20 million to 150 million individuals per square kilometer and spread over an area ranging from a few hectares to hundreds of square kilometers. Adult swarms of Desert Locusts can migrate several thousand kilometers while hopper bands move only a few kilometers. Fledgling swarms make the longest flights of all adults, traveling up to 1,000 km in a week (93).

Experts generally agree that rain and the availability of new vegetation create conditions conducive for the transformation of solitary insects into gregarious bands or swarms (93). **Outbreaks**–marked population increases leading to the appearance of gregarious groups-follow successful breeding. Three processes are involved: the concentration of solitary locusts in one area, their subsequent multiplication and, finally, the

Figure 1-1- Life Cycle of the Desert Locust



NOTE: The relative sizes of the five instar hoppers and adult Desert Locust, shown at approximately one-half actual size.

SOURCE: A. Steedman, cd., *Locust Handboo k* (United Kingdom: Overseas Development Natural Resources Institute, 1988), p. 20.

gregarization process (83). Sometimes solitary locusts breed successively in one location; other times they congregate in new breeding sites. The resultant crowding produces gregarious behavior (83).

Physiological changes in the insects' appearance also are associated with the gregarization process and maybe dramatic. Some species change so markedly that solitary and gregarious forms were originally described as different species. Often, solitary phase locusts resemble the color of their habitat, whereas gregarious phase locusts are brightly colored. In addition, color changes may occur with sexual maturity. For example, solitary Desert Locusts are pale gray or beige when sexually immature but males turn pale yellow when mature. Gregarious Desert Locusts are bright pink when sexually immature fledglings and bright yellow when mature.

Gregarious behavior is used often to distinguish locusts from grasshoppers. However, some species of grasshoppers behave periodically in a gregarious manner–multiplying rapidly and producing swarms like locusts Population increases maybe started by unusual weather or certain changes in land use (93).

Generally, gregarious behavior in locusts and aggregating grasshoppers proceeds by intermediate or transition stages and it is reversible if conditions change. Also some species are highly gregarious whereas others are less so. Still other species' behavior falls on the continuum in between. It is therefore not surprising that experts differ in drawing the line between locusts and grasshoppers. For example, one OTA reviewer wrote, "the Tree Locust is categorized by some acridologists among aggregating grasshoppers because of [its] poor swarming behavior" (64). Others call the Sudanese Grasshopper the Sudanese Locust (71) and the Senegalese Grasshopper the Senegalese Locust (69).

Locust and grasshopper species vary in their food preferences. Some species (e.g., the African Migratory Locust, Red Locust, Brown Locust, and the Senegalese Grasshopper) prefer grasses, including economically important food crops such as corn, millet, sorghum, and wheat (95). The Tree Locust prefers trees, shrubs, and bushes. The Desert Lore@ on the other hand, eats a wide range of food (93), although some believe it prefers grasses but eats other vegetation only when necessary (54, 95).

Locusts and aggregating grasshopper represent the greatest danger to agriculture during their gregarious phase. One analysis of records of Desert Locust damage showed that 8 percent of crop damage is done by hoppers, 69 percent by immature and maturing swarms, and 23 percent by sexually mature adult swarms (93). Crop damage by hoppers is low because the breeding areas where hoppers hatch are mostly outside crop areas. But once gregarious swarms begin to migrate, the potential for damage increases. Individual locusts and grasshoppers can eat their own weight (up to 2 grams) in food every day. Desert Locust swarms are particularly large so their potential for damage is especially great. One-half million Desert Locusts, a small part of an average swarm, weigh approximately 1 ton and eat as much "food" per day as about 2,500 people (93).

Geographic Distribution and Migration Patterns

The regional distribution of each locust and grasshopper species varies from year to year, but the species involved in large-scale outbreaks called upsurges–show general patterns (figure 1-2). For several species, outbreak areas, those permanent breeding and gregarization areas,

Figure 1-2–Distribution of Major Species of Locust and Aggregating Grasshoppers in Africa and the Middle East

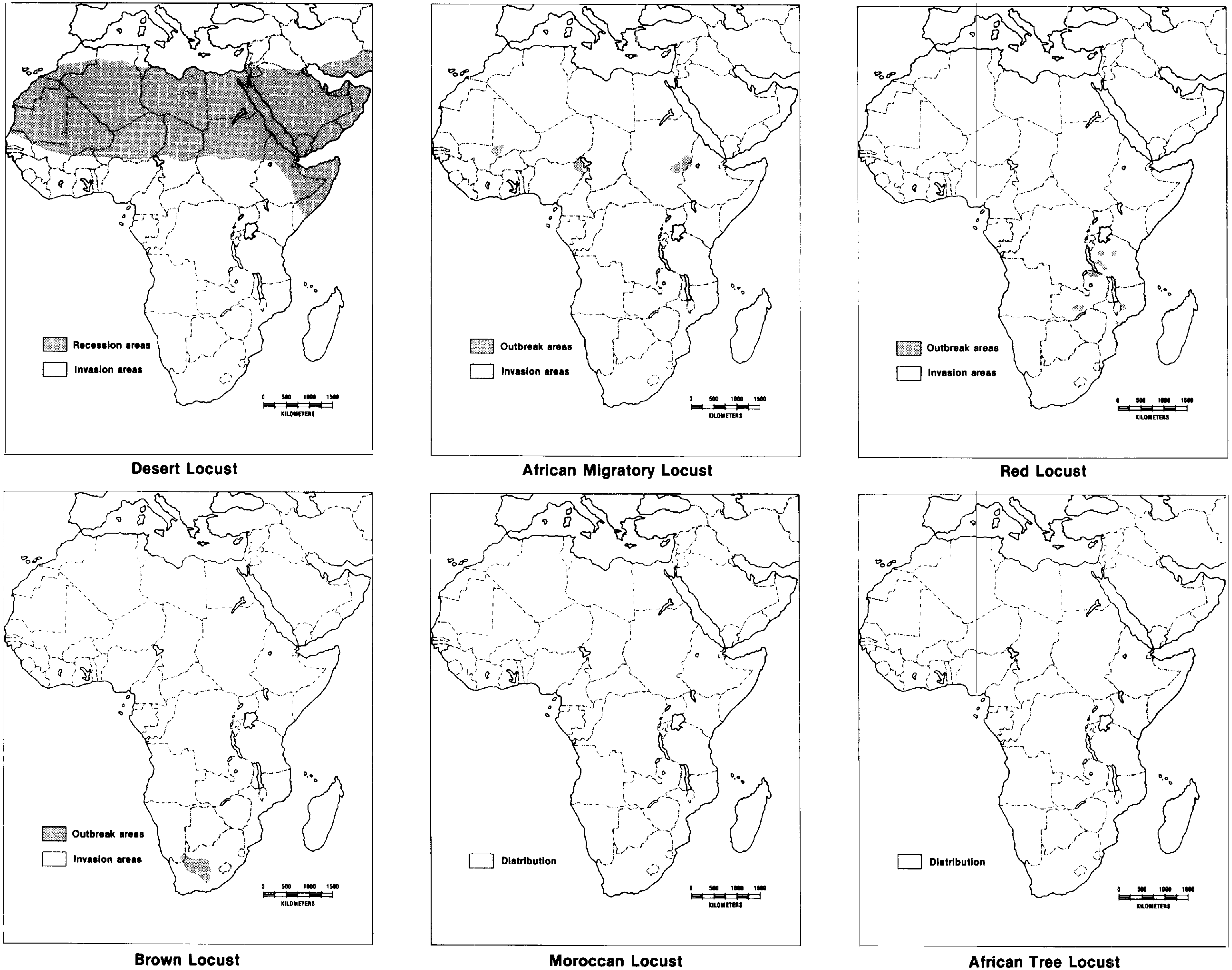
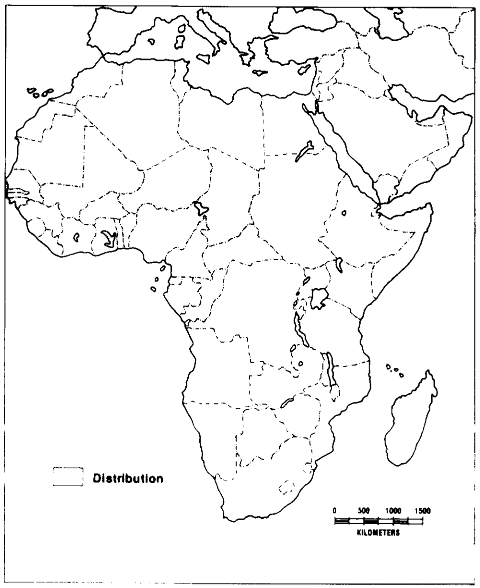
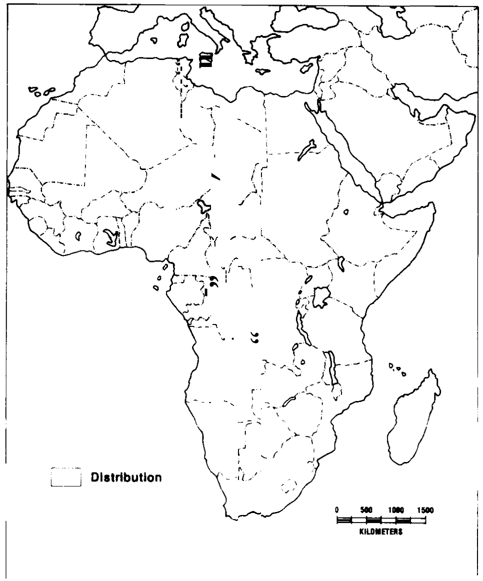


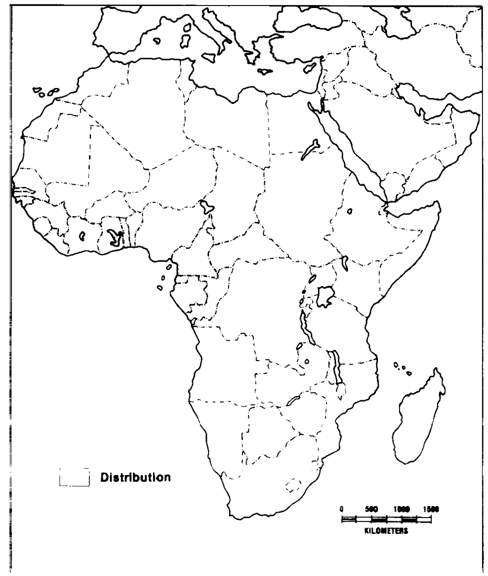
Figure -2–Distribution of Major Species of Locust and Aggregating Grasshoppers in Africa and the Middle East–Continued



Senegalese Grasshopper



Sudan Plague Locust



Variegated Grasshopper [a]

NOTE:
[a]OTA reviewers from East Africa noted the presence of the Variegated grasshopper in Uganda, Kenya, Tanzania, Rwanda, and Burundi.

SOURCE: TAMS Consultants, Inc. and Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment*, Main Report, contractor report prepared for the U.S. Agency for International Development, March 1989, pp. C7-C23.

can be distinguished from larger invasion areas. For example, the Red Locust, the African Migratory Locust, and the Moroccan Locust all have defined outbreak areas. The larger, combined invasion areas of the major species cover virtually all of Africa

Desert Locusts have a particularly extensive distribution, with no localized or well-defined outbreak areas. Between outbreaks, bands and swarms are rare, and low-density solitary forms occupy the central, drier part of its distribution, known as the recession area. This vast desert and semi-desert north of the equator is about half the size of the invasion area. During plagues, migratory swarms of the Desert Locust may penetrate all of the invasion area–nearly 20 percent of the world's land area. Up to 57 nations in Africa, the Middle East, and Asia (and Spain and Portugal in Europe) may be affected (93).

Certain zones exist within the Desert Locust's recession area that are particularly suitable for breeding and formation of gregarious groups. These zones constitute a small part of the total recession area (12, 54). Locusts moving into such a seasonal breeding area may be further concentrated by wind convergence and moisture, laying their eggs in constricted sites. Major Desert Locust outbreaks occur when the amount and frequency of rainfall enables insect numbers to build from one generation to the next (71). Should the build-up continue long enough, a plague results. A Desert Locust plague occurs when many gregarious bands and swarms occur at the same time over a large area in different regions (12, 93). While Desert Locust outbreaks are frequent, upsurges large enough to start plagues are rare. More frequently, potentially dangerous, partially gregarious populations die down without producing bands or swarms, usually because of weather conditions but sometimes because parasites and predators kill hoppers (93).

Locusts and grasshoppers cause recurrent problems for Africa, the Near East, and Southwest Asia. Locust outbreaks are usually attributable to one species in a given area and they occur intermittently but irregularly. The Desert Locust in particular has widespread, sporadic, and unpredictable upsurges. Grasshopper outbreaks often involve a number of species with widely varied biological characteristics and cause chronic agricultural damage each year (93). The Sahelian region of Africa is particularly vulnerable.

Locusts' migratory patterns are affected by prevailing seasonal winds, topography, and temperature. Normally, insects drift downwind until they encounter conditions suitably moist for breeding and feeding. Nevertheless, broad seasonal patterns of movement are detectable. For example, in West Africa, summer Desert Locust breeding occurs in the Sahel and swarms produced there generally move from east-to-west north of a weather pattern known as the Inter-Tropical Convergence Zone and west-to-east to its south. Winter breeding areas are located in the Mahgreb countries and swarms move mostly north-to-south from there. Weather conditions also affect specific insect migration routes. For example, fragments of Desert Locust swarms reached the Caribbean with the aid of October 1988 storms. They crossed the Atlantic from West Africa-a distance of 5,000 kilometers–in a period estimated from several days (85) to a week (54). Mountains in Morocco, Algeria, Yemen, and Iran, highlands in Ethiopia, and the escarpment in SaudiArabia affect wind patterns which, in turn, influence the direction and speed of locust movement. For example, the Anti-Atlas Mountains south of the Seuss Valley forma topographical barrier to northward-moving swarms. Low temperatures, commonly found at higher altitudes, stop flight activity and hatching and prolong insect development. Deserts, however, do not seem to impede movement.

Changing land-use patterns also influence the distribution of grasshoppers and locusts. Alreadya variety of environmental changes has led to certain changes as natural vegetation gives way to cultivated land, as irrigation brings moisture to areas, as cultivation disturbs eggpods, or as vegetation is reduced. For example, the Red Locust's importance declined in Mauritius as agricultural land expanded and locust populations became less dense (36). Likewise, the normally gregarious African Migratory Locust today is behaving more like a nongregarious grasshopper due to the break-up of its habitat in Mali (118). On the other hand, the Variegated Grasshopper, a minor nuisance in the 1930s, became a major problem in the 1970s following widespread forest clearing for coffee production in the Ivory Coast. The pest flourished in the environment created by certain weeds that invaded clearings (71). Similarly, Cavin (19) feels that desertification can be expected to increase the amount of habitat suitable for high intensity Desert Locust breeding.

LOCUST AND GRASSHOPPER UPSURGES, DECLINES, AND THE ROLE OF CLIMATE

Early civilizations knew that locust plagues occurred intermittently. Since then, people have tried without success to predict upsurges.

No evidence exists of regular intends between major or regional Desert Locust plagues of the last century (138) and no method is known to predict whether upsurges or declines will occur in a given year. Scientists can detect sequences of rainfall suitable for the types of outbreaks that lead to upsurges using modern surveillance and weather forecasting techniques, e.g., satellite remote sensing and computerized mathematical models. But they are unable to predict weather patterns sufficiently in advance to know whether an upsurge will actually materialize.

On the other hand, the mechanisms of Desert Locust upsurges have been described qualitatively and, in some cases, quantitatively. 'Upsurges," "outbreaks," and "plagues" are relative terms and no generally accepted, quantifiable standard exists for defining when a plague begins. Thus, experts differ in their analysis of the number and timing of the last century's plagues. The most thorough analysis of the upsurges and declines of the Desert Locust showed that seven major plagues, lasting from 7 to 22 years each, occurred in the 112-year period from 1860 to 1972 in Africa, the Middle East, and Southwest Asia (138, figure 1-3). Statistical analysis revealed two kinds of plagues in the individual regions: those lasting a year or so and those lasting 6 to 8 yearn.

Most agree that the last *major* plague subsided in 1962 to 1%3 (70, 93). Several major Desert Locust upsurges occurred since then: 1%7 to 1968, 1977 to 1978, and 1986 to 1989, but these were shorter and less extensive than earlier plagues (70, figure 1-3). Disagreement exists whether these upsurges in the 1970s (95) and 1980s reached plague status. FAO considers that the most recent upsurge, at least that portion which occurred in 1988, did qualify as a plague and was similar in scale to that in most years from 1950 to 1%2.

Ako, mo6t experts agree that locust and grasshopper upsurges are heavily influenced by meteorological factors. For example, the main factor (apart from locust invasions from the outside) associated with 1860 through 1972 Desert Locust plagues seemed to be above-average winter and s ring rains (138). Researchers have sought corre ations of plagues with drought, wind circulation, even sun spots. The Inter-tropical Convergence Zone is of particular interest because areas of converging air masses are mo6t likely to receive rain and the swarm position can be related to this Zone (93).

Some contend that plague decline also is principally due to environmental causes, especially climatic factors (e.g., B.P. Uvarov, founder of the Anti-Locust Research Center in London). However, Waloff (138) concluded that". . . the causes for the [Desert Locust] plague declines remain obscure." Also, two researchers developed a mathematical model that could account for plagues and recessions of the Desert and Red Locusts over the past century without including environmental information (5). The main controversy regarding the decline of plagues is over the impact of control.

Most agree that widespread plague dynamics are influenced by successive conditions in seasonal breeding areas and areas where migrations occur, as illustrated here by the recent Desert Locust upsurge (figure 1-4). The first migrants probably entered the Sahel in late 1986 and swarmed into northwest Africa in late 1987, following favorable conditions that led to formation of gregarious swarms in the seasonal breeding areas around the Red Sea and in parts of the Sahel in 1985 and 1986. Following successful winter breeding in North Africa in early 1988, large numbers of swarms migrated south joining locusts breeding in the Sahel because of the abundant rainfall there (74). Lucas Brader (12) of FAO attributes the decline of the Desert Locust in late 1988 and early 1989 to three factors: efficient control campaigns in the affected countries, the loss of a large number of swarms from the Sahel in the Atlantic Ocean, and unfavorable breeding conditions (mainly low rainfall and low temperatures) during the winter and

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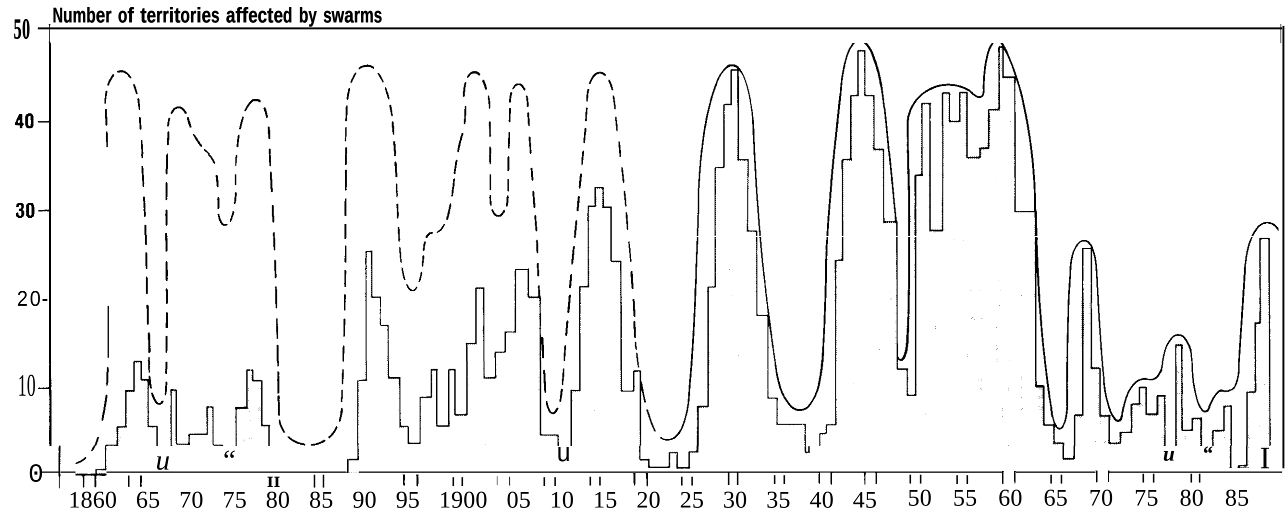
Figure 1-3—Major Plagues of the Desert Locust



NOTE: The undulating line above the graph outlines the plagues and recession periods, the broken portion suggesting the extent of infestation during the period 1860-1924 when records were incomplete.

SOURCE: Zena Waloff, "Some Temporal Characteristics of Desert Locust Plagues," *Anti-Locust Memoir 13* (London: Anti-Locust Research Center, 1976). Updated by Joyce Magor, "Joining Battle with the Desert Locust," *Shell Agriculture, No. 3, 1989*, p. *13.*

spring breeding season in Northwest and East Africa. Throughout the period, USAID, FAO, and others were predicting that the plague would continue for times ranging from 1 to 10 years.

In summary, the reasons for the start of a locust or grasshopper upsurge are relatively well known, though inability to forecast weather precludes accurately predicting when upsurges will occur and their duration. Reasons for plagues' subsiding are less clear. Specifically, the importance of control in declines is debated (see ch. 2).

ORGANIZATIONS INVOLVED IN LOCUST AND GRASSHOPPER CONTROL

Many locust and grasshopper control responsibilities of the colonial period were shifted in the 1950s to FAO, along with the mandate to coordinate bilateral and multilateral activities. Newly formed national crop protection agencies and regional organizations supplanted colonial structures as African nations achieved independence in the 1960s.

Bilateral donors also play important roles. France and the United Kingdom continued to play important roles in locust and grasshopper control until 1985. USAID provided approximately 20 percent of all donor funding of the most recent campaign and assigned it some priority in its African programs (table 1-1).

National Crop Protection Services and Other National and Local Groups

The national crop protection services, under the Ministry of Agriculture in most countries, have the mandate to protect crops. Therefore, they are the major national organizations responsible for grasshopper and locust control and take over when problems exceed the capacity of individual farmers. Generally, the crop protection services organized and carried out ground surveys and spraying in recent control campaigns, using four-wheel drive vehicles. Aerial spraying—often executed under regional and/or donor auspices in the Sahel—was used for more extensive or remote infestations or when the crop protection services could not meet needs.

Additional Ministry of Agriculture agencies also were involved in control efforts: agricultural extension agents assisted in monitoring, conducting control, and organizing local participation. National research and forestry services contributed knowledge, skills, and resources. Other government agencies, too, took part in the large control campaigns; these included public health departments, weather bureaus, customs services, and transportation ministries. In some countries, military pilots assisted with aerial spraying.

Local farmer brigades were a major component of the ground surveillance and control efforts in some countries. In Mali, 400,000 hectares were treated by ground spraying in 1988, and 45 farmer brigades received high praise for their effectiveness. Their expertise was developed in the previous 2 years' efforts: experienced farmers used hand or backpack sprayers and untrained ones used dusters. Niger reportedly had 10,000 five-person farmer brigades; Chad, 1,000 brigades with 10,000 farmers (99). Farmer committees were trained to recognize buildups of the Senegalese Grasshopper and initiate control in Burkina Faso, Gambia, Mali, Niger, and Sénégal (19, 71).

USAID estimates that the affected countries contributed $28.5 million in fiscal year 1988 and $124 million in fiscal year 1989 of their own funds to locust/grasshopper control (33). This was nearly as much as the donors provided in those years. For example, in fiscal year 1989, the governments of Morocco, Algeria, and Tunisia contributed $76 million, $58 million, and $10 million, respectively. Sudan, Somalia, Mali, and Sénégal contributed from $1 million to $4 million each. Many seriously affected countries, however, were Sahelian nations with little revenue to support the control effort.

Regional Organizations

Three semiautonomous regional organizations–the Desert Locust Control Organization for Eastern Africa (DLCO-EA), the Joint Locust and Bird Control Organization (OCLALAV), and the International Red Locust Control Organisation for Central and Southern Africa (IRLCO-CSA)–and three regional FAO commissions deal with migratory pests that transcend national boundaries in Africa, the Near East, and Southwest Asia (see table 1-2 and figure 1-5).

The organizational structure, mandate, membership, programs, and financial support of the African regional organizations continue to evolve. The most well-established of the regional organizations is DLCO-EA, founded in 1962 by Ethiopia, France (for Djibouti), Kenya, Somalia, Tanzania, and Uganda and joined by Sudan in 1968. Its main objective is control of the Desert Locust, but in 1976 its Council of Ministers decided to undertake control of grain-eating birds (e.g., the quelea), armyworms, and tsetse flies when locusts are in recession (63).

OCLALAV, created in 1965 to counter the Desert Locust and grain-eating birds, was restructured in March 1989 into a West African information and coordinating organization without an operational capacity. Its earlier operational role in survey and control was carried out by FAO during the recent upsurges and then was reassigned to the national crop protection services. In turn, the crop protection services' representatives began discussions with the Sahel Institute (INSA) of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) regarding a regional approach (99). A previous regional crop protection project of CILSS was terminated in 1987, following withdrawal of USAID funding. The CILSS-associated meteorological organization AGRHYMET continues to provide valuable weather information to members.

Currently, IRLCO-CSA suffers from a lack of member states' payments, but its situation is improving, following locust and grasshopper upsurges in the region, and donor assistance is being sought (12). On the other hand, the International African Migratory Locust Organization was dissolved in 1986 (102).

The three regional FAO Commissions for Controlling the Desert Locust (for Northwest Africa, the Near East, and Southwest Asia) were begun in 1971, 1967, and 1964 respectively in areas where locust survey and control were already the responsibility of national structures. (In sub-Saharan Africa, survey and control were principally done by regional entities then (106)). These Commissions support survey, control, training, and research. Member nations set policy and determine control activities, whereas FAO coordinates the work and serves as secretariat.

U.N. Food and Agriculture Organization

The U.N. Food and Agriculture Organization (FAO) has been the principal coordinator of international locust and grasshopper control campaigns since the early 1950s, a role confirmed by the U.N. General Assembly in December 1988. Initially, FAO

Figure 1-4-Movement of Desert Locust Swarms, January 1985 -April 1989

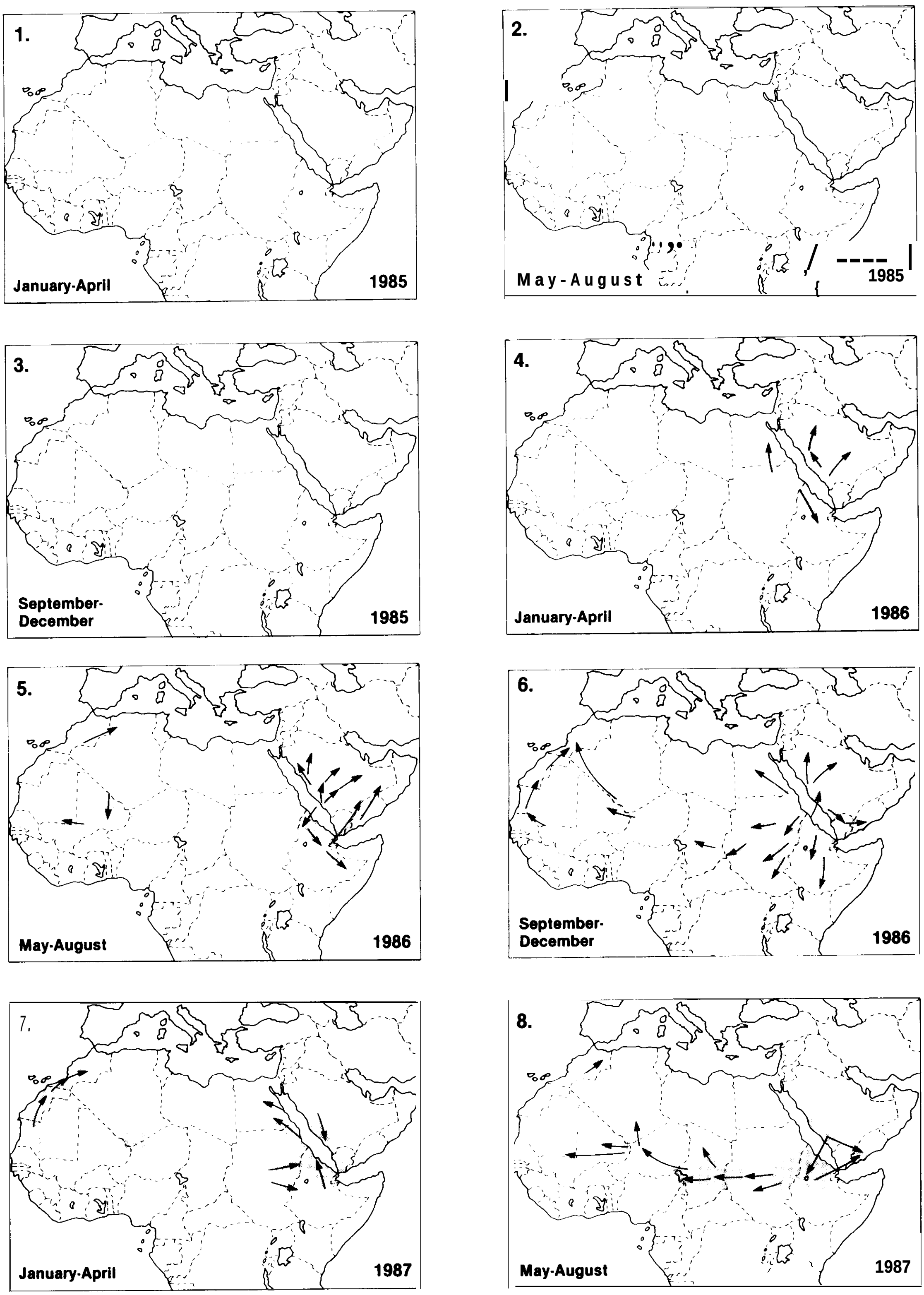
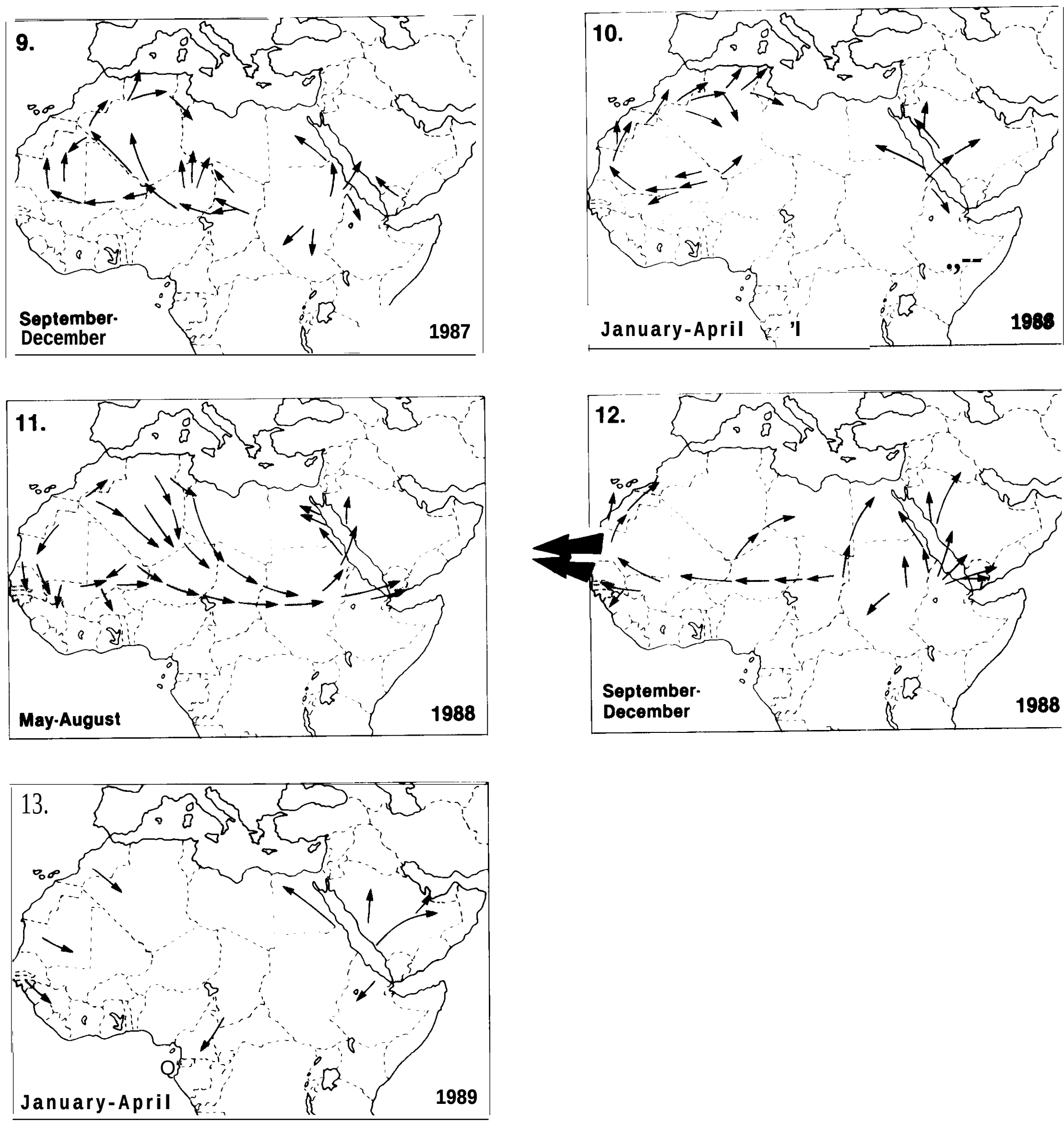


Figure 1-4—Movement of Desert Locust Swarms, January 1985-April 1989—Continued



SOURCE: PRIFAS "The SGR Saga in 13 Images," prepared by M. Launois and G. Blanca (Montpelier, France, 1989).

Table l-l-Donor Assistance to Locust and Grasshopper Control Programs, 1986-89 (U.S. dollars/calendar year)

Donors	1986	1987[a]	1988	1989 (Jan.-May)	Total
Bilateral donors:					
Algeria	50,000	146,882	180,000	0	376,882
Australia	0	0	205,000	0	205,000
Austria	0	0	29,041	0	29,041
Belgium	130,000	266,714	500,000	1,300,000	2,1%,714
Canada	3,014,500	2,802,238	2,243,000	343,000	8,402,738
China	500,000	*	40,000	120,000	660,000
Denmark	692,500	635,369	2,813,068	2,400,000	6,540,937
Finland	400,000	0	208,455	75,000	683,455
France	1,792,537	3,491,738	6,030,127	3,150,000	14,464,402
Germany (FR)	3,025,887	6,209,031	11,992,000	14,250,000	35,476,918
Greece	50,000	0	160,000	0	210,000
Indonesia	0	10,000	25,000	0	35,000
Iran	0	0	7,500	0	7,500
Israel	0	*	0	0	*
Italy	2,659,000	2,471,386	2,994,675	1,000,000	9,125,061
Japan	1,288,000	*	4,100,368	13,620,000	19,008,368
Kuwait	0	0	1,000,000	0	1,000,000
Libya	0	0	1,212,000	0	1,212,000
Luxembourg	0	140,000	244,000	0	384,000
Morocco	20,000	0	320,000	0	340,000
Netherlands	2,350,000	1,850,000	6,592,347	0	10,792,347
Nigeria	0	0	400,000	0	400,000
Norway	3,127,000	1,500,000	1,615,000	2,000,000	8,242,000
Portugal	0	0	606,000	0	606,000
Qatar	0	0	12,000	0	12,000
Saudi Arabia	0	0	2,860,000	0	2,860,000
Spain	62,511	0	2,440,000	0	2,502,511
Sweden	1,185,929	0	2,599,386	0	3,785,315
Switzerland	403,000	92,790	944,268	338,000	1,778,058
Thailand	11,000	0	0	0	11,000
Tunisia	0	0	90,000	0	90,000
Turkey	0	0	500,000	0	500,000
United Kingdom	1,909,183	987,687	5,800,000	207,000	8,903,870
USAID	9,1%,245	6,983,332	21,599,859	12,000,000	49,779,436
U.S.S.R.	0	*	1,376,000	0	1,376,000
Yugoslavia	64,000	0	0	0	64,000
Subtotal bilateral donors	31,931,292	27,587,167	81,739,094	50,803,000	192,060,553

Table I-1—Donor Assistance to Locust and Grasshopper Control Programs, 1986-89 (U. S. dollars/calendar year)—Continued

Donors	1986	1987[a]	1988	1989 (Jan.-May)	Total
Multilateral donors:					
African Development Bank	**165,000**	0	200,000	6,019,730	*6,384,730*
Banque Africaine de Developpement Africain (BADEA)	**750,000**	0	0	0	*750,000*
European Economic Community (EEC)	**10,739,981**	**2,348,674**	9,600,143	**400,000**	*23,088,798*
Islamic Development Bank	**0**	**0**	14,400,000	**2,044,000**	*16,444,000*
Organization of African Unity (OAU)	**0**	321,430	*300,000*	0	*621,430*
Organization of Petroleum Exporting Countries (OPEC)	**300,000**	0	*39,000*	0	*339,000*
UN Children's Fund (UNICEF)	**86,000**	*	10,000[c]	0	*%,000*
UN Development Program (UNDP)	1,839,000	*54,000*[b]	**2,926,332**	0	*4,819,332*
UN Environment Program **(UNEP)**	0	0	*48,405*	0	*48,405*
UN Food and Agriculture Organization **(FAO)**	2,601,000	*20,000*	4,700,000	610,000	*7,931,000*
UN World Food Program (WFP)	18,000	0	0	0	*18,000*
UN World Health **Organization** (WHO)	**4,480**	0	0	0	*4,480*
Subtotal multilateral donors	**16,503,461**	**2,744,104**	**32,223,880**	**9,073,730**	**60,545,175**
Non-Governmental Organizations	**1,211,460**	**133,000**[c]	**1,111,000**	**0**	**2,455,460**
Total	49,646,213	30,464,271a +20,000,000[d] 50,464,271	115,073,974	59,876,730	255,061,188 +20,000,000[b] 275,061,188
USAID as **percent** of total	**18.5%**	**22.9%**	**18.7%**	20.0%	**19.5%**

NOTES:

*Amount unknown (1987).

[a]Includes only assistance to Sahelian and West African countries.

[b]Includes only assistance to two of four recipient countries.

[c]Includes only assistance from section aid to Gambia.

[d]An additional $20 million was given by donors for programs in Northwest African countries, Sudan, Ethiopia, and Yemen (Jeremy Roffey, Emergency Center for Locust Operations, FAO, personal communication, June 26, 1989).

SOURCES:

Column 1: Jeremy Roffey, '1986 Funding Chart for Grasshopper and Locust campaigns in Africa" (Emergency Centre for Locust Operations, U.N. Food and Agriculture Organization, Rome, December 1986).

Column 2: U.N. Food and Agriculture Organization, "Report of the Meeting on the Evaluation of the 1987 Grasshopper Campaign in the Sahel, Annex V (Emergency Centre for Locust Operations, Rome, December 1987).

Columns 3 and 4: U.N. Food and Agriculture Organization, "Assistance Provided to Countries and Regional Organizations," Report of the Thirtieth Session of the FAO Desert Locust Control Committee, AGP:DLCC/89/4, Rome, Italy, June 12-16, 1989.

Table 1-2-Independent Regional Organizations and Their Member Nations

Organization	Member States	Headquarters
DLCO-EA: Desert Locust Control Organisation for Eastern Africa	Djibouti, Ethiopia, Sudan, Somalia, Kenya, Tanzania, Uganda	Addis Ababa, Ethiopia
OCLALAV: Organisation Commune de Lutte Antiacridienne et de Lutte Antiviare/Joint Locust and Bird Control Organization	Chad, Cameroon, Benin, Gambia, Ivory Coast, Niger, Mali, Mauritania, Senegal	Dakar, Senegal
IRLCO-CSA: International Red Locust Control Organisation for Central and Southern Africa	Kenya, Uganda, Tanzania, Zambia, Malawi, Zimbabwe, Botswana, Swaziland, Mozambique	Ndola, Zambia

SOURCE: Dale G. Bottrell, ''Locusts and Grasshoppers in Africa and the Middle East,'' contractor report prepared for the Office of Technology Assessment, January 1989.

focused only on Desert Locust problems, but its scope was broadened later to include other migratory pests.

The FAO Desert Locust Control Committee (DLCC) is the overall intergovernmental body that coordinates all Desert Locust-related control and research. In 1955, the United States was a founding member of the DLCC and remains one of some 50 member countries The Emergency Centre for Locust Operations (ECLO), created in 1986 and housed in FAO's headquarters in Rome, bears operational responsibility within FAO. It assumed responsibility for raising donor funds and coordinating control activities during the recent upsurge. ECLO has handled approximately $10 million in aid each year since 1986 in addition to coordinating some 150 projects funded by bilateral and multilateral donors, including FAO itself (109).

FAO's activities include:

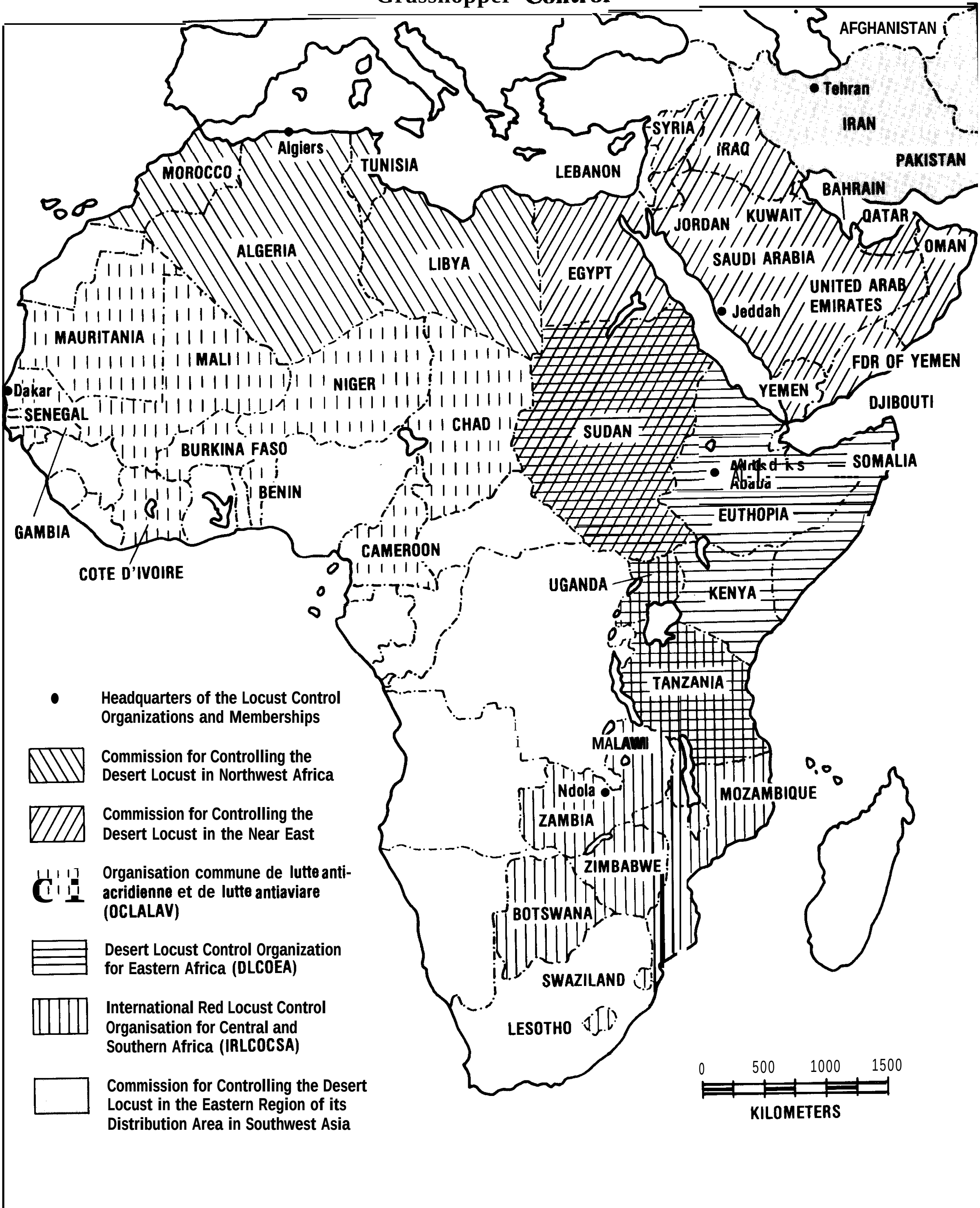
- supporting a centralized Desert Locust reporting and forecasting service in Rome;
- preparing and distributing the monthly FAO/ECLO Desert Locust Bulletin, special bulletins on other locusts and grasshoppers as need@ and a semiannual research registry beginning in 1989;
- organizing international meetings for representatives of donors and national governments;
- sponsoring research and training on locust surveillance and control; and
- implementing locust projects financed by FAO, the United Nations Development Programme, and the international community.

Also, FAOcoordinates activities of the African regional locust and grasshopper control organizations and sponsors the FAO regional Commissions in Africa and Donor Coordination Committees in each country receiving assistance.

USAID and Other Donors

Many donors contributed large amounts of money during the recent plague, principally for insecticides and spraying equipment, but also for training and technical assistance, vehicles, rotective clothing, radios, and spare parts. FAO's data indicate that total donor expenditures for programs

Figure l-5—Regional Organizations and FAO Commissions in Charge of Locust and Grasshopper Control



SOURCE: TAMS Consultants, Inc. and the Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment,* Executive Summary and Recommendations, contractor report prepared for the U.S. Agency for International Development, March 1989, p. Exsum-11.

in affected countries were at least $49.6 million in 1986, $50.5 million in 1987, $115.1 million in 1988, and $59.9 million through mid-1989, for a grand total of $275 million committed through mid-1989 (table 1-1).

As a result of donor and African countries' efforts, approximately 7.6 million ha of land in 10 Sahelian and West Africa countries alone received aerial or ground insecticide treatments in 1986 and 1987, mostly against grasshoppers (table 1-3). In 1988, 10 million ha were sprayed in Northwest and West Africa, mostly against Desert Locusts (12).

The United States, through USAID, provided an average 20 percent of all donor contributions through mid-1989 to Northwest and sub-Saharan Africa. Data from USAID show U.S. expenditures, by fiscal year, totaling $58.8 million from 1986 to 1989: $7.4 million in fiscal year 1986, $7.5 million in fiscal year 1987, $20.4 million in fiscal year 1988, and $23.0 million in fiscal year 1989 (table 1-4). In 1988 and 1989, this amounted to approximately 4 percent of U.S. development assistance to sub-Saharan Africa (123).[1]

The United States has provided financial and technical assistance to locust and grasshopper control efforts in Africa since the 1950s. During the 1945 through 1963 upsurges, U.S. monetary contributions were less than the United Kingdom's and FAO's. However, in the 1950s and 1960s, the United States provided technical specialists and helped establish the DLCO-EA. Following a widespread grasshopper outbreak in the Sahel in 1974 and 1975, USAID set up a Regional Food Crop Protection Project to strengthen national services in West Africa and funded the CILSS Integrated Pest Management Project in the Sahel. In addition to supporting projects bilaterally in the various African nations, the United States helps Finance the work of FAO/ECLO.

USAID provides assistance through its Africa (AFR) and Asia and the Near East (ANE) regional bureaus, the Bureau for Science and Technology (S&T), the Office of Foreign Disaster Assistance (OFDA) and its missions (box 1-C).

OFDA is responsible for short-term emergency assistance (3 to 6 months) and replaced AFR's temporary Office of Emergency Operations in taking the lead in USAID locust and grasshopper control efforts in 1987 (99). In July 1988, the AID Administrator created the Desert Locust Task Force, under the aegis of OFDA. The Task Force included staff from the various USAID bureaus (AFR and ANE), offices (contracts and legal sections, Public Affairs, Legislative Affairs, etc.) and missions; the State Department; the U.S. Department of Agriculture (USDA); the U.S. Environmental Protection Agency (EPA); the U.S. Geological Survey; and others. It met weekly before dissolving on June 1, 1989, following the decline of the locust swarms.

The regional bureaus' Offices of Technical Resources and S&T are responsible for longer-term development assistance but also managed the Africa Emergency Locust/Grasshopper Assistance project. Financial aspects of U.S. multilateral assistance (e.g., to the U.N. Development Programme and FAO) are handled by the Department of State's Bureau of International Organization Affairs.

USAID often hires outside technical expertise from U.S. consulting firms, universities, and USDA USDA's Office of International Cooperation and Development, for example, used $2.6 million of USAID from 1986 to 1989. Of this, $1.5 million supported technical experts from USDA agencies, such as the Animal and Plant Health Inspection Service and the Forest Service, and $1.1 million was spent on supplies for control campaigns (3).

Other U.S. agencies assist in control efforts, For example, the U.S. Geological Survey provided "greenness maps" showing where vegetation was abundant following rainfall; EPA staff, working with USAID, advised African governments on safe disposal of surplus insecticides and empty containers; and U.S. Peace Corps volunteers participated in the Mauritania control campaign (119).

In addition to official government donors, a number of private, nongovernmental organizations (NGOs) provided assistance to African countries

[1] The Development Fund for Africa is the baseline against which these contributions were measured. This Fund does not include Food for Peace (Public Law 480), Economic Support Funds, or multilateral assistance.

Table I-kTotal Area Controlled in the Sahelian Countries in 1986 and 1987

	Ground (ha)		Aerial (ha)		Total (ha)	
	1986	987	1986	87	1986	1987
Mauritania	100,000	22,365	193,000	225,200	293,000	247,565
Senegal	300,000	36,556	1,159,800	134,872	1,458,800	171,428
Gambia	11,500	12,104	247,710	41,940	259,210	55,044
Mali	68,000	2,329	484,000	166,866	552,000	169,195
Burkina Faso	20,893	0	211,140		232,033	9,062
Chad	25,222	42,428	143,700	212,55!	186,922	254,983
Niger	151,414	75,420	270,505	230,834	421,919	3&,&4
Cameroon	0	54,000	0	0	0	
Guinea Bissau	0	9,000	0	0	0	9:000
Nigeria	0	0	0	0	60,000	60,000
Total	677,029	254,202	2,709,855	1,012,267	3,403,884	1,322,531

SOURCE: TAMS Consultants and Consortium for International Crop Protection, *Locust* and *Grasshopper Control in Africa/Asia: A Prograromatic Environmental Assessment*, Main Report, contractor report prepared for the U.S. Agency for International Development, March 1989, p. D-37.

affected by locusts an grasshoppers. Some of these organizations used U.S. foreign aid in addition to their own funds for these programs. Oxfam, Band Aid, CARE, Save the Children, Caritas, and World Vision were among the organizations that provided insecticides, vehicles, spraying equipment, and first aid kits. Band Aid made the largest single NGO contribution, donatingaplanetoMa "for aerial spraying (82).

Donor-Sponsored Research

Many organizations engaged in locust and grasshopper control also carry out related research. And some primarily research organizations are beginning to examine improved control methods. The International Center on Insect Physiology and Ecology in Nairobi, Kenya and the International Institute for Tropical Agriculture in West Africa are among the latter.

Some donors fund locust *and* grasshopper research projects by their own scientists, such as the United W i n ' s Overseas Development Natural Resources Institute and the French grasshopper and locust research unit of the Center for International Cooperation in Agricultural Research for Development. On the other hand, USAID contracts out scientific research, usually to private consulting firms and universities. The Locust Research Task Force of the Special Program for African Agricultural Research of the World Bank maintains a computerized directory of donor-sponsored research. It listed 151 projects being planned or conducted in the Sahelian countries as of January 1989. Some of these projects involve collaboration with African research institutions and/or researchers, while others are solely donor efforts.

PAST AND CURRENT CONTROL METHODS FOR LOCUSTS AND GRASSHOPPERS

Often, individual farmers do nothing when faced with locusts or grasshoppers. But they also developed a variety of cultura and physical controls before the availability of chemical ones (table 1-5). Almost all these methods have been used in the' United States and Canada, too. Physical and cultural control methods continue to be practiced, alone or in combination with chemical control, especially against small infestations in crops or hopper bands near croplands. For example, some farmers combine the use of pesticides with fire, burning roosting locusts at night (32). Village brigades in Chad herded hopper bands into deep trenches and buried them in the recent campaign

Table 1-4—U.S. Assistance to Locust/Grasshopper Programs, Fiscal Years 1986-89

country	1986	1987	1988	1989	Dollars
Sahel and West Africa					
Burkina Faso	$268,800	$591,732	0	0	$860,532
Cameroon	200,000	200,000	0	0	400,000
Cape Verde	0	0	75,000	25,000	100,000
Chad	990,841	1,254,211	1,305,730	0	3550,782
Gambia	35,000	594,898	( )[a]	25,000	654,898
Guinea Bissau	29,000	290,320	0	0	319,320
Mali	1,287,080	1,012,433	1,775,110	200,000	4,274,623
Mauritania	154,000	227,500	1,446,964	866,256	2,694,720
Niger	61,000	337,386	1,199,647	317,000	1,915,033
Sénégal	1,657,349	1,923,752	245,892	3,362,320	7,189,313
Sahel Regional	244,000	0	0	0	244,000
East and Southern Africa					
Botswana	1,183,587	0	0	0	1,183,587
Ethiopia	75,000	380,516	407,820	13,800	877,136
Sudan	1,024,948	600,000	662,415	173,713	2,461,076
Tanzania	50,000	0	0	0	50,000
Zaire	10,860	0	0	0	10,860
Zambia	100,000	0	0	0	100,000
East Africa Regional	0	0	0	0	0
Northern Africa and S.W. Asia					
Algeria	0	0	1,070,032	18,866	1,088,898
Jordan	0	0	0	152,600	152,600
Morocco	0	0	5,295,713	10,308,974	15,985,203
Pakistan	0	0	0	2,000,000	2,000,000
Tunisia	0	0	1,361,447	1,410,535	2,771,982
Yemen	0	135,598	0	0	135,598
African Regional	75347	0	5.578.414	4.123.988	9.777.749
Total dollars	**$7,446,812**	**$7,548,346**	**$20,424,184**	**$22,998,052**	**$58,797,910**
Amount of total granted to FAO	**4,084,587**	**358,000**	**2,465,000**	**1,508,910**	**8,416,497**
Amount of total, OFDA funds[b,c]	**7,171,012**	**6,384,059**	**9,643,950**	**5,585,652**	**28,784,673**

NOTES:

[a] Assistance to Gambia in 1988 and some in 1989 included in amount for Senegal.

[b] U.S. assistance consists of OFDA funds, USAID mission funds, Africa or Asia/Near East Bureau regional funds, and some local currency. In fiscal year 1988, OFDA contributed $9,643,950, the missions $4,840,600? the re ional programs $6,689,656, and local currency $2,350,464, for a grand total of $23,524,670. In fiscal year 1989, OFDA contributed #,585,652, the missions $15,847,400, the regional programs $1,565,000 and local currency $1,850,343, for a grand total of $24,848,395. Thus, the percent of OFDA funding decreased significantly in 1988 and 1989.

[c] Information in this line from John Gelb, 1989, below.

SOURCES:

1986-John Gelb, Office of Foreign Disaster Assistance, AID, "USG Contributions to Locust/Grasshopper Threat in Africa-FY 1986 as of September 30, 1986," n.d.

1987-Office of Foreign Disaster Assistance, "Insect Infestation," OFDA Annual Report Fiscal Year 1987 (Washington, DC: USAID, 1988).

1988-Office of Foreign Disaster Assistance, "Insect Infestation," OFDA Annual Report Fiscal Year 1988 (draft) (Washington, DC: USAID, 1989).

1989–John Gelb, Office of Foreign Disaster Assistance, "U.S.A.I.D. Support, Desert Locust Task Force, FY 1987-89," dated July 22-23, 1989. Due to the decline of the locust problem in early 1989, some of the funds allocated have been reprogrammed for other crop protection activities.

Box 1-C–USAID's Operational Responsibility for Locust/Grasshopper Problems

Several groups within USAID have responsibility for various aspects of the United States' contributions to addressing locust and grasshopper problems in Africa. These include the Office of Foreign Disaster Assistance, the Bureaus for Africa and Asia and the Near East, and the Bureau for Science and Technology.

1. Short-term–The Office of Foreign Disaster Assistance (OFDA) has the authority and responsibility to apply its resources to:
   - emergency pest situations in a host country when a disaster has been declared by the U.S. Ambassador to that country,
   - the mitigation of potential disaster situations, and
   - certain recovery and rehabilitation activities designed to prevent secondary disaster effects.
2. Medium-term–The Bureaus for Africa and Asia and the Near East have the authority and responsibility to:
   - implement nondisaster project activities required to put the pest emergency situation back under control; and
   - implement normal, longer-term development initiatives, vis-a-vis pest control programs.
3. Long term–The Bureau for Science and Technology, working with the Bureaus for Africa and Asia and the Near East, has the authority and responsibility to support development activities on a regional or bilateral basis, designed to improve the capabilities and capacities of national and regional institutions.

SOURCE: Adapted by OTA from TAMS Consultants and the Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment*, Main Report, contractor report prepared for the Agency for International Development, March 1989, pp. D1-D2.

(119), using what is probably the most effective traditional control.

Some traditional control methods are sometimes ineffective, e.g., plowing fields infested with pods (12). And some other means, e.g., planting resistant varieties of sorghum, cultivating grasslands, fallowing agricultural land, or rotating crops, are effective against some species but not others. For example, cassava, a root crop, is planted in some areas as a security against locusts but it is very vulnerable to attack by the Variegated Grasshopper (71). Planting rooted sorghum plants instead of seeds in flood-recession irrigated areas can protect crops from the Sudan Plague Locust but not other species (12).

Most traditional controls have been replaced by the use of chemical insecticides, at least in official control programs. Numerous synthetic organic insecticides are available now. The first chemical treatment, used from the 1880s through the 1940s, was an arsenic-poisoned bait. Baiting could be done by unskilled labor, but buying, storing, and transporting tons of wheat bran for bait made this costly, remote breeding sites were missed, and sometimes the pests did not eat the bait (79). In the 1940s and 1950s, first ground, and then aerial, spraying techniques were introduced and the persistent organochlorines BHC (benzene hexachloride) and dieldrin became the insecticides of choice (34, 79). In the 1960s, dieldrin was most often used against Desert Locust hopper bands and

Table 1-5—Examples of Locust and Grasshopper Control Methods

Cultural methods	. Planting of security crops such as cassava . Crop rotation . Use of resistant or tolerant plants . Good land management (avoidance of deforestation, overgrazing, and heavy fallowing) . Planting short-season crop varieties or seeding or harvesting early or reseeding
Physical methods	. Beating or trampling on the hoppers . Digging up egg pods or plowing fields infested with egg pods . Scattering straw over roosting sites and then burning it . Lighting fires or making noise to prevent swarms from settling in crops . Driving hoppers into trenches and burning, drowning, or crushing them . Use of flame throwers . Use of horse-, tractor-, or truck-drawn collecting machines
Biological methods	. Running poultry in crops . Use of cattle to eat off and trample grass in locust breeding grounds . Introduction of pathogens
Chemical methods	. Use of conventional chemical insecticides . Use of botanical compounds, e.g., neem extracts

SOURCES: Compiled in Dale G. Bottrell, "Locusts and Grasshoppers in Africa and the Middle East," contractor report prepared for the Office of Technology Assessment, Washington, DC, January 1989, p. 24, from: D.L. Gunn, "Systems and Management–Strategies, Systems, Value Judgments and Dieldrin in control of Locust Hoppers," *Philosophical Transactions of the Royal Society of London, Series B, Vol. 287,1979,* pp. 429-445; C.F. Hemming *The Locust Menace,* Centre for Overseas Pest Research, London, 1974; J. Ledger, *African Wildlife,* vol. 41,1987, p . 197-210; J. Rofley, 'The Effects of Changing Land Use on Locusts and Grasshoppers, pp. 199-206, *Proceedings of the International Study Conference on Current and Future Problems of Acridology,* London, 1970; TAMS Consultants and Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment,* Main Report, contractor report prepared for the U.S. Agency for International Development, March 1989.

BHC against adult swarms (55). Also, BHC was used against Brown Locust upsurges in South Africa from the late 1940s through the 1980s (52). Dieldrin has been used against Red Locust outbreaks since the 1950s (79).

Initially, dieldrin and the other persistent pesticides seemed to be a major technological advance. Dieldrin, for example, remains toxic for 30 to 40 days on vegetation and longer in soil, despite rain or sun (34, 118). Hopper bands were controlled by spraying swathes of vegetation with dieldrin, forming "barriers" in front of marching bands. Since dieldrin acts as a stomach poison that accumulates over time, the insects eventually ingested a lethal dose by eating treated vegetation. Low doses were effective and respraying was unnecessary, even if a second hatching occurred (54, 104).

concern mounted in the 1970s regarding the heavy use of persistent pesticides. DDT, the prototype persistent organochlorine, was banned by the United States in 1972 and dieldrin came under increased scrutiny. Studies in developed countries in the 1960s showed substantial traces of dieldrin in human tissue. High levels of dieldrin are known to cause convulsions in humans and the chemical is responsible for 13 recorded deaths (104). The evidence of dieldrin's carcinogenicity is strong in mice, weaker in other experimental animals, and inconclusive or negative in humans (17, 104, 137). EPA canceled most dieldrin uses inthe United States in 1974 and European countries also banned its use. EPA cited dieldrin's carcinogenicity, bioaccumulation, hazards to wildlife, and other chronic effects (134).

USAID routinely sponsored overseas use of pesticides in the 1970s that EPA banned or restricted for use in the United States. In 1975, four environmental organizations sued USAID for failure to prepare an environmental impact statement (EIS) on these pesticide uses, as required by the 1969 National Environmental Policy Act. USAID, in response, prepared an EIS in 1977 and issued a pesticide policy the following year prescribing how pesticides should be treated in USAID activities (8). Since the 1978 publication of Regulation 16 (22 Federal Code of Regulations Part 216), the United States has required environmental assessments prior to approving purchase or use of pesticides overseas with U.S. funds. The chlorinated hydrocarbons dieldrin, lindane, and BHC could neither be purchased nor used in U. S.-supported efforts. USAID environmental offices in Washington approved individual USAID missions' requests for various insecticides depending on what was known at the time (43). Beginning in 1977, various amendments to the Foreign Assistance Act further required that USAID consider the environmental impacts of its overseas projects and specifically undertake activities to maintain and restore natural resources in developing countries (127).

The USAID policy on pesticides served as a model for other donors for developing regulations on their use of pesticides in Third World countries. The World Bank promulgated Guidelines *for the Selection and Use of Pesticides in Bank Financed Projects and Their Procurement When Financed by the Bank in 1985,* developed with the assistance of the United States. In the same year, FAO passed an *International Code of Conduct on the Distribution and Use of Pesticides.*

The type of insecticides used in African locust and grasshopper control programs has shifted markedly away from the persistent organochlorines (dieldrin, BHC, aldrin, and lindane) although some use continues (table 1-6). At least one-half of OTA survey respondents identified the use of BHC, dieldrin, and lindane in the past but only one or two respondents indicated their current use. Some European countries still allow the use of lindane, closely related to BHC chemically (12). The insecticides most commonly used for controlling grasshoppers and locusts in Africa are fenitrothion and malathion (10). These organophosphates are principally contact insecticides with short residual action (2 to 3 days) (118).

Most donors have requirements to purchase pesticides from domestic companies ("tied aid"), and USAID did so, by and large, even though purchases funded with OFDA money are exempt from these provisions due to their emergency nature. Fenitrothion, introduced by Sumitomo and independently by Bayer, is Japanese-owned and manufactured in the large quantities needed for locust control in Japan and Europe. Malathion is manufactured in the United States and elsewhere. Dieldrin is no longer produced in significant quantities in the United States, where it was developed, or in Europe. Thus, malathion was a major component of U.S. donations.

Table 1-6—Insecticides Used Presently and in the Past Against Locusts and Grasshoppers in Africa and the Near East

Name	Insecticide: Commercial name[a]	Insecticide: FAO[b]	OTA[c]	Present use: OTA[c]	Present use: LHB[d]
Aldrin				x	x
Alphacypermethrin	Fastac	x			
Alphamethrin		x		x	
Arsenic compounds			x		
Bendiocarb	Ficam	x	x		
BHC, Benzene Hexachloride			x	x	
Carbaryl	Sevin		x	x	
Chlorpyrifos	Dursban	x	x		
Darslean			x		
DDT				x	x
Dichlorvos	DDVP		x		
Deltamethrin	Decis	x	x		
Diazinon	Basudine	x	x	x	
Dieldrin	Ensodil		x	x	
DNOC				x	x
Esfenvalerate		x			
Fenitrothion	Sumithion Folithion	x	x	x	
Fenvalerate		x			
Heptachlor					x
Isobenzan					x
Lambdacyhalothrin	Karate	x	x		
Lindane			x		
Malathion		x	x		
Para-oxon					x
Parathion	PenCap				x
Propoxur/Phoxim	Undine	x	x		

NOTES:
[a]Illustrative examples, since many commercial brands exist.
[b]FAO's list of pesticides are those used on a substantial scale for Desert Locust control.
‘Pesticides listed are those that OTA'S survey respondents indicated as currently used for locust/grasshopper control, regardless of the scale of that use.
‘Insecticides no longer used for either locust or grasshopper control.

SOURCES:
FAO: U.N. Food and Agriculture Organization, Emergency Center for Locust Operations, "Pesticides for Desert Locust Control: June 1989 Update," *African Locust Bulletin*, N. *14/89*. June 20, 1989, pp. 6-7.
OTA: Responses to OTA survey, 1988.
LHB: Steedman, A., *The Locust Handbook* (London: Overseas Development Natural Resources Institute), 1988, p. 119.
Name/commercial names: USAID, Locust/*Grasshopper Management: Operations Guidebook (Washington,* DC: January 1989), pp. VII-4-5, and PRIFAS, *SAS Newsletter,* No. 8, Aug. 7, 1989, p. 37.

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Chapter 2

What Is The Problem?

VARYING PERCEPTIONS OF THE PROBLEM

Finding: ***Many** views exist on various **aspects of** locust and **grasshopper problems** but these have **not** been widely **debated** nor **resolved. Instead, many host-country** and **donor policymakers** base **control policies and programs** on **certain assumptions: that** locusts **and grasshoppers are a** serious problem, **that** pesticides **are** the way **to** control them, and that **control programs** have substantial benefits for most **farmers and herders. OTA finds** these **assumptions** questionable.*

Locust and Grasshopper Outbreaks as Disasters

To many, especially the general **public**, the recent upsurges of locusts and grass**hoppers** in Africa seem to pose a major threat to that continent's **already** precarious food security. The New ***York Times*** proclaimed: "Locusts Threaten Sub-Sahara Africa With Famine" (April 24, 1988, p. 14) and "The Cloud Over Africa Is Locusts" (November 11, 1988, **p.** A3). This **perception** is one of large swarms of resects, stripping vast areas of vegetation. Also, people assume that these insects are the most damaging pests facing African farmers and herders and the problem seems unsolvable because, after all, locusts have caused @agues since biblical times. In many minds, these resect outbreaks are **inevitably** linked to famine and the popular press has rein**forced** this view.

Many aspects of the public policy response to locust and grasshopper problems match this perception. For example, the U.S. Agency for **International** Development (USAID) **organized** a special Desert **Locust** Task Force within the Office of Foreign Disaster **Assistance (OFDA)** to **manage U.S.** contributions to control efforts. Earlier locust and grasshopper outbreaks had been treated in much the same way, with special control efforts, by donors and regional and national organizations. **The contributions of** donors, *$275* million from **early 1986** through mid-1989, reflect this view of averting plague-induced disaster.

The resources committed by **USAID,** $59 million **from fiscal year** 1986 through fiscal year 1989, indicate the high **priority given** to this officially declared emergency.

Many within the expert community, especially those who work with grasshopper and locust **control,** agree with this assessment of the disastrous impact of locusts and grasshopper on **African** agriculture. The problem is perceived as serious enough to warrant specialized attention and to mobilize substantial donor and host country resources. Most people who responded to OTA'S survey **(app.** B) noted that locust and grasshopper problems are **"very** serious" in the areas with which they are familiar, with the **1986** to 1989 outbreak being as serious as any on record Also, approximately one-half of the **respondents** rank locusts as the most serious pest in **their** area.[1]

Certainly locusts can devastate vegetation over sizable **areas, especially** if swarms are moving slowly and stay in one place **for** several days. The potential for national-level drops in agricultural production exists if swarms affect areas crucial to a country's economy. Any loss of food crops to locusts or grass**hoppers** puts some **people** at risk in localities where **food** supplies are **already** precarious.

For example, the African Migratory **Locust** destroyed 50 percent and 40 percent, respectively, of Kenya's wheat and **corn crops** in a peak infestation in 1931 (15), although this level of loss did not occur in the recent upsurge. In northwest Mali, crop losses to **grasshoppers** were estimated at 20 to **30 percent** in 1985 **despite** spraying pesticides on 900 km^2 and, in 1986, some **farmers'** millet crops were destroyed three times before they eventually abandoned some fields or planted **sorghum** instead because of its resistance to these resects (93). The Variegated Grasshopper can

[1] **Certain** aspects of OTA's **survey** may have led respondents to exaggerate the magnitude of **these** problems: some questions were not precise enough regarding the time and geographic areas of outbreaks; the response rate was low (2S **percent)** and people who **perceive** the problem to be serious are those most likely to complete a lengthy form; many of the respondents are affiliated with locust and grasshopper control programs; and the questionnaire was sent at the peak of the **recent** upsurges.

cause up to 65 percent yield loss in cassava if it strips leaves, bark, buds, and shoots late in the season (93).

Overview of the Debates

Other experts, commonly entomologists who are not involved in control efforts, make quite a different assessment of the threat posed by locusts to African food security. They suggest that the severe, localized nature of these outbreaks almost ensures that their importance be improperly exaggerated relative to other pest problems. These experts note that locusts and grasshoppers occur in large swarms infrequently. For example, outbreaks occur often, but upsurges that lead to a plague are rare (93). In this, the analogy to a natural disaster such as a tornado is apt. In a given location, the situation may be disastrous but the impact, measured over a wider area and/or for a longer time period, may have little significance.

Thus, many in this second group of experts conclude that current public policies are based on questionable or faulty assumptions. A significant number of OTA'S contractors and reviewers agree, in general, with this position although they hold a range of views on specific aspects of the problem.

Assumptions provide a needed basis for preliminary answers to important policy-related questions in the absence of reliable data and:

> ... the experience of using insufficient data that are of uncertain quality to make critical determinations about the use of scarce resources, is nothing new in the Third World. (72, p.2)

Unresolved, major discrepancies in how experts view locust and grasshopper problems now, however, have significant repercussions for congressional and other policy decision making. Moreover, the lack of debate on important issues outside a small group of scientists and control experts means that those who see the situation as disastrous, warranting massive spraying, often carry the day.

Specific, significant areas of debate include: 1) the insects' impact on food production; 2) the importance of locusts and grasshoppers in relation to other pests; and 3) whether or not these insects cause famine. Experts' judgments differ, too, concerning 4) the effectiveness of current control Programs based exclusively on the use of chemical insecticides, 5) the relative roles of climate and control in bringing about declines of insect upsurges; and 6) whether the benefits of control, in terms of crops saved, exceed the costs of control. Experts differ, also, in their opinions on the nature and severity of costs in terms of 7) human health and safety and 8) environmental impacts. People also disagree on 9) how control efforts should be organized and what strategies should be followed.

LOCUSTS AND GRASSHOPPERS' IMPACT ON FOOD PRODUCTION

Finding: The link between locust and grasshopper upsurges and food shortages or famine is questionable. In fact, locusts and grasshoppers are relatively minor pests in terms of overall crop losses, although they can devastate local areas for short periods of time. Thus, the high priority given to locust and grasshopper control programs is unwarranted.

Do Locusts Cause Famine?

USAID, like others, justifies its locust and grasshopper control program on the basis of averting famine. The 1987 USAID *Locust/Grasshopper Strategy Paper* defines the purpose of the strategy as:

> **... dealing with one of the most serious exogenous factors adversely affecting agricultural production: the cyclically recurring infestations of locusts and grasshoppers, which can result in significant crop losses and periodically lead to plague and famine conditions in many parts of Africa. (113, p.1)**

More recently, USAID stated that the goal of its $22 million African Emergency Locust Grasshopper Assistance (AELGA) project, fiscal years 1987 through 1989, is "to contribute to the improved nutritional status and well being of Africans by reducing the threat of locust and grasshopper plague-induced famine, and its associated economic and social suffering."

Key data are missing, but historical analysis (16) and recently acquired data (72) suggest that what is often considered fact–the connection between swarming insects and famine-is actually a questionable assumption.

Crop loss from locusts and grasshoppers may be **severe in** certain **areas** without having significant impact **on** national crop production. USAID country reports reveal little overall crop damage by Desert **Locusts** during 1988, the height of the recent plague–crop losses of 2 percent **in** Sudan and Mali (**with some** localized **severe** damage –and minimal **or** negligible losses **in** Niger, Chad (117), and Algeria (89). The authors of the Chad case study **claim** that effective control **was the** reason for the small losses, but also admit that **no system exists** for reliably evaluating crop damage by locusts.

The **insects'** impact is highly dependent **on a** number of variables, including the number of **insects** present, how long they stay **in** the area, and the amount each insect **eats** (16). However, the stage of crop development also determines the amount of crop loss. Total crop loss usually occurs only if the **insects** attack **at** certain stages **in** crop development. Young grain crops **are** highly vulnerable but replanting maybe possible if they **are** destroyed early. Damage **to** more mature crops is usually lower until just before grains begin **to** ripen; nevertheless, **a** swarm **can cause partial or** total crop loss (95) . At other stages, damage is substantially less. For example, **one** study of the African Migratory Locust's effect **in** Kenya showed that the pest **caused** 100 percent yield loss when attacking very young **or** flowering corn, 20 percent yield loss on corn with unripened ears, and **no** yield loss **on** corn **over** 30 **cm** tall (139).

Economic losses **also** depend **on** which plant species and what part of the plant locusts affect, e.g., consuming grain or foliage or breaking branches due to their weight. Grain crops are highly susceptible at the "milky grain" stage and 100 percent yield loss may occur if even low densities of locusts or grasshoppers attack then. Studies on the impact of locusts on sugarcane yields in several countries showed that the highest recorded crop loss was due to Red Locusts in Mozambique's sugarcane fields, where yield was reduced by an estimated 33 percent in 1934 (95). Sugar-cane losses of 12 to 18 percent were more usual (in South Africa in the 1950s and the Philippines in the 1930s), but inone case yield increased after defoliation (95). Also, the weight of roosting locusts may break branches of trees, affecting future yields of valuable commercial crops.

As a result, crop losses are unevenly distributed in space and time, even during upsurges. Within affected areas, sometimes all vegetation is stripped, especially in sites such as breeding areas and traditionally infested areas, e.g., in Sudan, Ethiopia and Somalia, or when unusual weather conditions trap locusts in one spot for an extended period of time. In most infested areas, however, damage is less than total and uneven due to swarms' mobility and other factors.

Comparatively small **areas of the total area infested by Desert Locusts experience losses in excess of 10 percent (16). This occurred in the 1954 through 1955 season when nearly 90 percent of the total reported damage was in a small part of southern Morocco and in 1958, when a higher percentage was concentrated in two small areas in Ethiopia, causing severe, but localized, economic losses (16). The U.N. Food and Agriculture Organization (FAO) speculates that, on average, crop damage does not exceed 5 percent over the Desert Locust's whole invasion area during a plague (12). However, data to verify this percentage would be difficult to obtain. Grasshoppers, the Senegalese Grasshopper in particular, caused more generalized and heavier damage than locusts in recent years (12). No areas within nine West African countries studied have been affected severely enough by locusts and grasshoppers to be abandoned by cultivators (95), thus illustrating the temporary nature of damage.**

The location and timing of grasshopper and locust infestations, along with the food preference of the species involved, means that damage is not evenly distributed among different types of farmers and herders. For example, orange trees were severely attacked by Desert Locusts in Morocco's Seuss Valley in late 1954 and early 1955, so commercial growers were hard hit. But the Senegalese grasshopper adversely affects most of the millet- and much of the sorghum-growing areas of the Sahel (71) and, thus, subsistence farmers bear much of the damage.

Some insect species prefer grains and pose a greater threat to farmers than herders. Generally, herders seem to be less affected by locust swarms than farmers, probably because swarms occur when rainfall is plentiful, thus providing abundant

vegetation for grazing. Also, herders often can move their herds from damaged areas. Locusts and grasshoppers are more likely to affect herders adversely if their movement from devastated areas is restricted or if overgrazing already has reduced grass cover (95).

Substantial crop damage may lead to local adverse impacts on food security. Beyond this, little can be said with much certainty. Locust and grasshopper damage contributed to 1986 and 1987 food deficits in some countries but perhaps no more than other factors (72). In 1986, FAO estimated that crop losses due to locusts and grasshoppers in nine Sahelian countries was $31.0 million, 1.5 percent of the total value of agricultural production or 1.0 percent of total production. The relationship between this figure and that of other years or other outbreaks is not known (95).

The damage associated with locust and grasshopper outbreaks often results from the interaction of multiple adverse factors over time in addition to large numbers of insects: drought, loss of vegetation, civil strife, economic stagnation, etc. Most of these factors also contribute to famine or food shortages. Therefore, the impact of locusts and grasshoppers alone is difficult, if not impossible, to determine. On a countrywide basis, the recent locust or grasshopper upsurges did not have the negative impact that a drought would produce. Generally, the aggregate amount of damage reported was much less than feared and the losses were on the scale of localized, perhaps near-normal stress rather than national calamities (table 2-1). Some observers report that locust and grasshopper outbreaks often do not result in even local food shortages, because of replanting, regrowth of vegetation, use of resistant crops such as cassava and, especially, help from neighbors or relatives. Thus, the "popular image of a locust outbreak leading to famines seems to have little or no basis in fact." (95)

Famines have complex causes, as shown by recent examination of famines in Ethiopia from 1972 to 1974 (87) and the Sahel from 1968 to 1973 (86). Drought may set the stage, but other factors determine which groups are affected and by how much. The problem is more one of food distribution and food access than food production, since food shortages alone do not explain starvation. Neither aggregate food availability nor average consumption of food per person declined significantly in Ethiopia during one of the worst years of the famine (87). Apparently people starved because they could not afford to buy food from outside the area when their own farm output declined. Pastoralists were particularly hard hit in Ethiopia and the Sahel, but social, economic, and political factors, not the severity of drought, determined this. For example, the growth of commercial agriculture reduced herders' access to dry-season grazing areas in Ethiopia. In the Sahel, too, herders' traditional methods of ensuring against famine broke down: high taxes meant fewer herders could afford to store animals on the hoof; wildlife populations had declined so much that hunting could not replace domesticated animals; growing commercialization of agriculture had disrupted arrangements by which herders traded with farmers for access to cropland for dry-season grazing.

Given the complexity of such interactions, it is unlikely that the role locusts and grasshoppers play in famine could be assessed with aggregate food production data rather than information on local food availability. Data on local crop production losses and local shortages is essential but does not seem to exist, especially for food crops. Even national aggregate data commonly are only estimates. Locust and grasshopper control has taken place sporadically for decades and numerous organizations have been involved in this work. Yet the damage caused by these insects has not been documented accurately.

> ... the data is [sic] fragmented and episodic, reflecting outbreaks that were sufficiently large to merit the attention of an international agency or a government. ... There exist no accurate crop yield and/or loss data for most of the area subject to attack by locusts. (95)

In 1987, Oregon State University began USAID-funded work to improve the assessment of losses due to these insects. However, USAID's expectation that the International Plant Protection Center, using a computer model, could determine crop losses among several other objectives, proved overambitious. Most of the required data were spotty, unavailable, or unreliable and, thus, the model could not produce an improved crop loss assessment (99).

The number of variables involved complicates estimating potential crop losses and helps explains why the authors of so many published estimates of actual crops losses do not describe their methodology, having arrived at estimates subjectively. Measuring crop loss is difficult for migratory pests, especially the Desert Locust; people have made attempts in the past-and failed. Breeding areas are remote with access further limited by civil strife; upsurges can be large and widely scattered; and locusts are very mobile (16, 79). Experienced observers can estimate severe crop losses accurately in the local areas with which they are familiar, but miss more subtle yield reductions caused by these insects (16).

Pest Problems in Context

The relative importance of grasshoppers and locusts compared to other pests has not been determined precisely. Grasshopper and locust losses may be significant in some years. Yet compelling evidence does not exist that they cause worse losses than other pests (37, 72, 95). For instance, plant protection experts often assume that all types of preharvest crop losses in the Sahel region are as great as 30 percent but sometimes larger. Of this, grasshoppers maybe responsible for 5 to 18 percent of crop losses each year (72). In 1986, grasshoppers were considered a major problem and large-scale control programs were undertaken. Yet the 1986 crop production losses caused by grasshoppers seems to be below this normal range (table 2-l). These data, compiled for the Famine Early Warning System (FEWS) are the best available, although somewhat unreliable.

However, the 1986 FEWS data correspond with earlier estimates, many made before large control-campaigns existed. Compilations of reports on damage to crops and livestock in 40 countries during major Desert Locust plagues were made by the Anti-Locust Research Center in London for 1925 through 1934 and FAO for 1949 through 1958. Analyzing this information, F.T. Bullen found that the Desert Locust caused, on average, about 1.4 percent of the overall crop loss due to insects in the same area (or about 0.2 percent of the total crop production) and only about 4 percent in a peak plague year (or, only about O6 percent of total crop production). He concluded, "Locusts and grasshoppers, even at their worst, constitute only a very small proportion of the overall crop protection problem." (16)

In fact, weeds cause greater food crop losses in Africa than insects–15 to 35 percent of potential production depending on crop (millet, sorghum, rice, or maize) versus 10 to 20 percent, according to a standard reference-and locusts are not a major insect pest when examined overtime (25, as cited in 95). OTAreviewers concurred, noting, for example, that birds are the worst pest (32), the weed *Striga* costs farmers more losses (31), and the armyworm causes losses to cereal crops up to 30 percent in Zimbabwe in some years (61).

Finally, losses due to pests also must be placed in context-many other factors cause economic losses for farmers. For example, postharvest losses often account for a significant portion of spoiled production. In 1987, in West Africa and the Sudan, despite severe grasshopper infestations, losses to farmers due to inadequate marketing and storage facilities were greater than those caused by insects (12).

THE EFFECTIVENESS OF CONTROL PROGRAMS

Finding: The efficacy, efficiency, and equitability of locust and grasshopper control programs are undocumented or rely largely on anecdotal information. While insecticides undoubtedly kill insects and can protect standing crops, insecticides ' ability to end or prevent plagues is not clear. Nor have the economic benefits of control programs been demonstrated convincingly, especially for the low-resource farmers and herders who are most vulnerable.

The stated goals of control programs include preventing famine, saving crops and livestock, and preventing and ending plagues, but the link between the pesticide spraying campaigns and achieving these goals has not been demonstrated.

Control v. Climate

Many insecticides are effective for killing locusts and grasshoppers (95). However, the relationship between insect mortality and preventing crop or forage losses, in the area sprayed or distant from it, is uncertain. Also, it is not clear whether control campaigns prevent a plague from developing, hasten the end of a plague, or do not

Table 2-l-Crop Production Affected by Grasshoppers, 1986 (thousands of metric tons)

Country	Gross production	Production lost to grasshoppers		Production saved[b]		Production affected[b]	
		1,000s MT	Percent	1,000s MT	Percent	1,000s MT	Percent[c]
Burkina Faso	1,917.0	8.3	<1	91.5	5	99.8	5
Chad	685.0	24.0	4	30.0	4	54.0	8
Ethiopia	6,504.0	0.5	<1	0.5	<1	1.0	<1
Gambia	144.0	1.0	<1	1.0	<1	2.0	1
Mauritania	125.0	10.0	8	10.0	8	20.0	16
Mali	1,780.0	30.0	2	30.0	2	60.0	3
Niger	1,807.0	108.0	6	108.0	6	216.0	12
Senegal	964.0	50.0	5	70.0	7	120.0	12
Sudan	4,300.0	9.2	<1	9.2	<1	18.5	<1
All	18,226.0	241.0	1.4	350.2	1.9	591.3	3.2

NOTES:
[a]Original data from USAID, FAO, CILSS/FAO.
[b]Original data from FAO, FEWS estimates.
‘Percents lost and saved do not always equal percent affected due to rounding errors.

SOURCE: Price, Williams & Associates, “1986 Grasshopperand Locust Infestations,” FEWS Special Report No. 1, contractor report prepared for U.S. Agency for International Development, March 1987, pp. 4-12.

affect it. Some note the danger of broad-spectrum insecticides killing natural predators of these insects and the potential for developing pest resistance (which has not yet been known to occur for locusts). In these cases, insecticides could increase threats from locusts and grasshoppers indirectly.

Experts point out that control with chemical insecticides is the only effective method presently available for preventing locust and grasshopper outbreaks from becoming widespread (34, 38, 95). Generally, grasshopper control is considered less effective (95).

Some credit monitoring, surveillance, and control methods developed after World War II with reducing the duration and incidence of some species’ plagues or of reducing the intensity and geographic size of other species’ outbreaks when they do occur (54, 93). They contend that control efforts prolonged recessions between plagues of the Red Locust (5), the African Migratory Locust (2), and the Desert Locust (79). Generally, however, analysts admit that evidence was sometimes incomplete and circumstantial and that control sometimes has not been effective (4).

FAO contends that present control measures, properly applied, can prevent upsurges from developing into plagues or considerably shorten the duration of those that do develop (12). Furthermore, the failure to mobilize adequate resources and the inaccessibility of target areas, rather than ineffective methods themselves, caused several missed opportunities to prevent the Desert Locust upsurges from developing into a widespread plague in 1987 and 1988 in FAO’s view (106).

Others find, however, that control efforts have had negligible impacts on plague populations and that their decline is due almost entirely to natural causes (135). Support for this view comes from reviewing past Desert Locust and Brown Locust plagues. Plagues occurred for both insects at times when chemical control measures were used extensively (9, 52). For example, the Desert Locust plague from 1949 to 1%3 (when chemical controls were being deployed) was no less intense and lasted twice as long as plagues earlier in the century, which occurred before these control techniques were available (138, figure 1-3).

Climate is known to have a controlling effect on many aspects of locust and grasshopper behavior. Most believe that climate can retard locusts andgrasshoppers as much as control (95). But some believe that climate alone controls insects and that locust plagues end whether they are treated or not (135). If so, locust upsurges could be allowed to run their course at considerably less financial and environmental expense than current massive interventions. Such an approach would be analogous to the U.S. Forest Service's practice of usually letting forest fires bum, except where fires threaten lives or homes.

Not surprisingly, OTA'S reviewers similarly have points of view ranging from insect declines are entirely due to weather (63) to the control program was the major factor in curtailing the plague (44). Others (61, 79) believe that control campaigns definitely suppress plague development and hasten the end of a plague, but admit adverse weather may play a crucial role.

As a result, several conclusions are possible: "the question of whether the decline of the plague was due to [human intervention] or . . . nature remains unresolved" (71). Or, "*There* is no firm evidence that control campaigns have appreciably affected the declines" (9). The French research agency PRIFAS conjectured that 20 percent of the Desert Locust population was destroyed by control efforts in late 1988 and early 1989,30 percent perished in storms over the Atlantic, 30 percent were killed by low temperatures, and 20 percent by insufficient rainfall (76). FAO's Brader (13) concluded that:

> **While climate appears to be the dominant factor determining the fate of locust plagues, chemical control may play an important role at least on the national scale.**

Currently, FAO is supporting research by the British Overseas Development Natural Resources Institute examining the roles of weather and control in the sequence of events leading to the upsurge, spread, and decline of the Desert Locust plague between 1985 and 1989. The scientist coordinating that research said:

> **The usual view of those involved in control campaigns is that control measures are key in ending plagues. The more objective view–that of most scientists not involved in control-is that weather is key, that weather has as much if not a greater role than control. (54)**

Key data for resolving these differences of opinion regarding the impact of control programs are lacking. This includes accurate surveys of: the numbers of insects present in a given location and time during an infestation; baseline numbers of insects present during recessions; the percent of total production actually at risk; the actual amount of damage done to crops and other vegetation; the impact of this local damage on local and aggregate crop production. Similarly, specific information is needed on weather and control variables. For example, experts at a 1988 World Meteorological Organization workshop on meteorological contributions to locust control stressed the need for more case studies as well as improved coordination between weather and locust control operations (112). This missing information is key to making informed decisions regarding whether chemical control efforts are economically justifiable, where resources should be directed and when, the appropriate nature, timing, and quantity of emergency aid, and the amount of preparation needed to meet threats in succeeding years (73).

However, historical data can support previsional decisions and some data syntheses have been completed (e.g., 4). Based on these, it appears that, in some places and at certain times, certain kinds of control may help break a sequence of events that could lead to a widespread insect upsurge; under other circumstances, control can have negligible impact. For example, a kill rate of 95 percent might be required over a vast area when weather favors insect build-up; once rains decline, a lesser effort properly administered, can hasten what nature started (55). Other generalizations regarding the effectiveness of locust control are highly suspect and some costly decisions are being made with little data to support them.

"Pesticides of Choice" and Their Effectiveness

In August 1988, USAID waived Regulation 16 and identified malathion, carbaryl, and fenitrothion as the "pesticides of choice" and listed others that could be used in locust and grasshopper control (table 2-2). As a result of the waiver, USAID was not required to prepare an environmental assessment before pesticide use. The waiver was justified on the basis of a declared emergency and other environmental research planned and underway. For instance, the Agency had contracted with TAMS Consultants, Inc. (with technical input from the Consortium for International Crop Protection (CICP) headquartered at the University of Maryland) to conduct a Programmatic Environmental Assessment regarding locust and grasshopper control throughout Africa and Asia.

Also, USAID contracted with a private firm, Dynamac, to conduct trials of 6 to 8 insecticides for their efficacy; impact on nontarget, beneficial organisms; and residues in soil and on vegetation in Mali (against the Senegalese Grasshopper) and Sudan (against the Desert Locust) in 1987 through 1988. It was known that the relative effectiveness of various ingredients, formulations, and applications of insecticides must be assessed under field conditions and balanced against harmful effects, but this had not been done adequately. USAID hoped that the Dynamac trials would fill in some of these gaps.

With the reinstatement of Regulation 16 in August 1989 and based on the completed Programmatic Environmental Assessment, USAID expanded the number of insecticides that could be purchased or used-most with a number of restrictions and qualifications-to include propoxur, acephate, and cypermethrin (122).

USAID's approval only overlapped in part with the Environmental Protection Agency's (EPA) list of pesticides registered for use in the United States against grasshoppers and locusts. EPA registers malathion, carbaryl, diazinon, lindane, acephate, chlorpyrifos, and tralomethrin (with zyme) but not some others commonly used in USAID-approved locust control efforts, e.g., fenitrothion and propoxur. USAID's list allowed the United States to match other donors' approved pesticides more closely, at least for the major chemicals. However, lack of clarity existed in the field about which were best and why some pesticides approved for use in the United States were disallowed overseas. Advice from Washington regarding these policies was sometimes too slow in coming and voluminous to be helpful (120).

No single organization seems able to provide complete or accurate information on the quantities or types of pesticides used in Africa for any purpose, and some past estimates are known to be inaccurate (95). However, indications are that the total amount of pesticides used in 1986 to 1989 for locust and grasshopper control was formidable. Insecticide use seems to vary widely among countries, ranging from 34 to 1,014 metric tons in 7 individual Sahelian countries in 1986, for instance (95), and between regions. In 1988, the 4 northwest African countries of the Maghreb region used 11 million liters of insecticides and the 4 most affected Sahelian countries, 2 million liters, at a total cost on the order of $100 million (109).

Fragmentary data exist on the total amount of insecticides supplied by donors during the 1986 through 1989 locust and grasshopper control campaign, but it is not clear how accurate these figures are. Donors provide the same pesticide indifferent formulations so figures are difficult to summarize and compare. Also, FAO'S information does not include the amounts of pesticides purchased by African governments; these amounts are significant in the Maghreb but negligible in the Sahel (12).

U.S. assistance during the last campaign consisted principally of pesticides, airplanes, and equipment for spraying (figure 2-l). The United States provided 605,518 liters and 450 metric tons of insecticides in 1986 and 1987, according to the OFDA database (table 2-3). This was mostly malathion, carbaryl, and lesser amounts of propoxur and fenitrothion, at a cost of approximately $3.2 million. Apparently, carbaryl was purchased but not used (99) because spree African officials doubted its effectiveness and wanted quicker-acting chemicals.

The United States exempts emergency efforts, i.e., those supported by OFDA, from "tied aid" provisions, but these requirements apply to pesticide choice for longer-term efforts, e.g., those funded by USAID missions and bureaus, for which waivers are more difficult to obtain. In fact, most OFDA funds spent on pesticides went to U.S. manufacturers.

The use of U.S. manufactured pesticides and U.S. procurement requirements affected pesticide selection, control costs, and the speed with which pesticides reached Africa. USAID usually selected

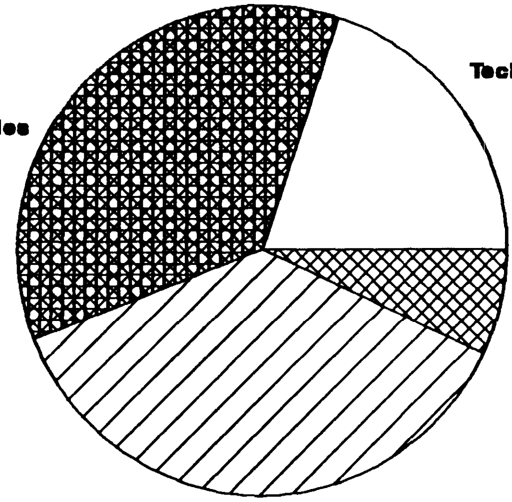
Table 2-2–International Registration Status of Locust/Grasshopper Insecticides in Selected Developed Countries

Insecticide	Canada[1]	France[2]	U.K.[2]	West Germany[2]	United States: Approved by AID[3]	United States: Registered by EPA[4]	United States: Registered by EPA for grasshopper/locust[4]
Main:							
Malathion	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Carbaryl	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Fenitrothion	Yes	Yes	Yes	N/A	Yes	Yes	No
Propoxur	Yes	N/A	Yes	N/A	No	Yes	No
Diazinon	Yes	Yes	Yes	Yes	Yes*	Yes	Yes
Lindane	Yes	Yes	Yes	Yes	No	Yes	Yes
Dieldrin	No	No	No	No	No	No	No
Acephate	No	Yes	N/A	Yes	No	Yes	Yes
Others:							
Bendiocarb (Ficam)	Yes	Yes	Yes	Yes	Yes*	Yes	No
Chlorpyrifos (Dursban)	Yes	Yes	Yes	Yes	Yes*	Yes	Yes
Cyhalothrin (Karate)[a]	No, (pending)	N/A	N/A	N/A	Yes*	No, (pending)	No
Tralomethrin (scout)	No	N/A	N/A	N/A	Yes*	Yes	Yes, in combo with zylene
Cypermethrin	Yes	Yes	Yes	Yes	No	Yes	No
Carbosulfan	No	Yes	Yes	N/A	No	Yes	No

NOTES:
N/A = not available.
* Approved with the qualification that use be monitored or justified.
[a]No approved common name exists for Karate, a trade name for a synthetic pyrethroid, according to *Farm Chemicals Handbook* 1989 (Willoughby, OH: Meister Publishing Co., 1989).

SOURCES:
1. Dr. Peter Bennett, Chemical Evaluation Division, Bureau of Chemical Safety, Food Directorate, Ottawa, Ontario, Canada, KIA OL2, January 1988.
2. European Directory of Agrochemical Products, Part 3, Insecticides and Acaricides, Royal Society of Chemistry, The University, Nottingham, England, NG7 2RD, 1984.
3. Insecticide approved from Aug. 1, 1988-Aug 15, 1989. Charles Gladson et al., "Waiver of Pesticides Procedures for Locust/Grasshopper Control Programs in AFR and ANE Regions," action memorandum for AID Administrator, Aug. 15,1988, Attachment A pp. 6-7. This differs from direction on pesticide selection in the *Locust/Grasshopper Management Operations Guidebook (1989). New* information requires that the list be updated constantly.
4. TAMS Consultants and Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment,* Main Report, contractor report prepared for USAID, March 1989, p. D-56.

Figure 2-l-Uses of U.S. Assistance for Locust/Grasshopper Control: $7.5 Million in Fiscal Year 1987



SOURCE: John Gelb, Office of Foreign Disaster Asistance, USAID, "U. S. .A.I.D. Support, Desert Locust Task Force, FY1987," June 22,1989.

Table 2-3-Pesticides Purchased With USAID Funds for Locust/Grasshopper Campaign: Fiscal Years 1986 and 1987

Pesticide	1986[a] Value[c]	1986[a] Volume[d]	1987[b] Value[c]	1987[b] Volume[d]
Carbaryl	0	0	*258,802*	*%,690* L
			217,739	50 t[f]
Fenitrothion	260,000	50,000 L[e]	205,000	5,000 L
Malathion	199,305	60,000 L	1,382,959	393,828 L
Propoxur	0	0	600,000	4oot
Unspecified	115,000	N.A.	0	0
Total	574,305	110,000 L	2,664,500	495,518 L 450 t

NOTES: N.A=Not available
[a]Recipient countries listed in 1986: Mali and Senegal.
[b]Recipient countries listed in 1987: Burkina Faso, Chad, Ethiopia, Gambia, GuineaBissau, Mali, Senegal, Sudan, and Yemen.
[c]Often "value" includes the cost of ocean and/or air freight.
[d]Active ingredients vary considerably (e.g., between 1 and 4 pounds per liter depending on the formulation).
[e]L=liter
't = metric ton.

SOURCE: Dennis King, USAID/OFDA, "O.F.D.A. Commodity/Service Report," Washington, DC, June 27,1989.

malathion and carbaryl because the pesticides are U.S.-manufactured and technical advisors from USDA had long-term experience using them for U.S. grasshopper control. Generally, U. S.-produced insecticides are more costly than those manufactured in other countries so tied aid provisions increase control programs' costs (30).

Also, various USAID procurement requirements affectin bureau admission money, including the need for competitive bids, were a major cause of delays in U.S. programs. USAID/Morocco noted that approximately 5 months were needed to purchase and ship insecticides in 1988 and 1989 because of these requirements (120). In Chad, the insecticidal arrival late also, but in this case the delay was not detrimental because the locusts had "mysteriously disappeared" (117).

Operational Effectiveness of Control

The use of insecticides may protect standing crops from grasshoppers and locusts. However, few detailed studies have been made of the operational effectiveness of the recent spraying campaigns, e.g., insecticides' efficacy in killing resects was not monitored. Also, insecticides were often used in ways that reduced or negated their effectiveness (54, 99).

Incorrect application methods and careless tar et selection reduced the effectiveness of control Some areas were sprayed too late in the day or when temperatures or wind speeds were beyond recommended ranges or that had already been sprayed. Mounting targeted control efforts was not a priority of USAID and others during this campaign. Some swarms were treated that posed little threat because they were not expected to reach croplands or because they had already laid eggs and their populations were in decline (54, 115). Opportunities to spray hopper bands, when the insects are more vulnerable and concentrated, were missed. Where hopper spraying was attempted, areas needing treatment were sometimes bypassed or unaffected areas sprayed because often hopper bands were not visible from the air.

This occurred, in part, because USAID, in its 1987 Strategy Paper, approved control operations against swarms wherever they might be, rather than emphasizing focused operations at specific places and insect life-stages.

The 1986 to 1987 spraying program was difficult to execute due to the widespread extent of infestations, lack of preparedness of staff, wars and civil strife, impassability of roads after rains, donors' diverging policies, lack of transport and communications, and late ordering and arrival of equipment and pesticides. Air shipments of supplies were more timely in 1987. Yet, some 1987 operations were not justified, necessary, or economical. Over-dosage of pesticides occurred in many ground and aerial operations. And parceling out the program among many donors meant that ground support was duplicated and sometimes efforts were not concentrated when and where they were needed (95).

The Economic Costs and Benefits of Control

The economic cost of control programs varies with insecticide, formulation, and application method. For example, carbaryl costs at least twice as much as malathion and fenitrothion ($4.50 v. $2.00 per ha). Ground application costs ranged from $6.00 to $8.50 per ha for ultra-low volume (ULV) spraying, $8 to $12 per ha for baits, to $18 to $26 per ha for dusts in Senegal in 1986. Aerial and ground ULV spraying cost approximately the same per hectare. However, farmers treated only 0.5 ha per hour, the crop protection service treated 8 to 12 ha per hour with ground spraying, whereas aerial spraying averaged 450 to 470 ha per hour (118). Multiengine aircraft are most costly per hour but can cover the largest areas; using smaller, single engine aircraft costs about $1,000 per hour.

These estimated costs for ULV spraying are comparable to current U.S. costs of grasshopper control, which range from $5.50 to $9.00 per ha. But these estimates assume that the pesticides are in place where needed and do not account for the freight of formulated chemicals. Air freight was a substantial cost in 1986 at the beginning of these campaigns. More realistic estimates of total donor and local costs in Africa range from $15 to $30 per hectare in 1986 (95). Thus, the actual costs of control programs in Africa are high.

The direct benefits of control campaigns can be assessed by estimating the value of crops threatened, or saved. Indirect benefits, e.g., institutional development of national crop protection services, also exist but are largely unquantifiable and, thus, not included.

The value of crops threatened depends on the crop, with cash crops' value more easily measured than those such as sorghum and millet, grown for direct consumption on the farm (15). Yet, much of the invasion area of the Desert Locust in Africa is devoted to subsistence farming and herding. Thus, the economic benefits of control programs for the most vulnerable are even less clear than those for large-scale commercial farmers. By and large, the micro-level economic and sociological research needed to make this determination has not been done.

The value of crops saved is more relevant than value of crops lost, a conclusion reached by the 1989 Programmatic Environmental Assessment and the Anti-Locust Research Centre in London in the 1960's (15). However, crops threatened is no easier to determine than crops lost.

The Programmatic Environmental Assessment summarizes the best available estimates of the costs of grasshopper and locust damage, but it provides little basis from which to derive the benefits of control. Existing measurements of benefits are subject to wide margins of error (92, 95). Economic estimates of potential agricultural losses to the Desert Locust commonly are based on hypothetical calculations rather than field data on crop losses and insect biology. Also, some underlying assumptions are faulty, such as assuming that damage is evenly distributed and total in a given area. Or, estimates maybe based on worst-case scenarios. For example, potential damage from Desert Locusts in Morocco was estimated at $125 million to $250 million in 1988, the value of all crops produced in the Seuss Valley and southern Morocco (115). But this estimate assumed that the intensity and scope of the damage in 1988 would equal that of 1954 and 1955. A technical advisor to the Moroccan Government present at the time believes that what occurred then was a freak event due to unusual weather that trapped 14 immature swarms in the narrow Seuss Valley for 6 to 8 weeks and its probability of recurrence is low (41).

Resultant claims of the value of crops saved due to control are questionable at best when based on faulty assumptions, hypothetical figures, and/or worst-case scenarios.

No estimates exist of what the cost would be of letting an infestation run its course, although some instructive historical evidence exists, such as records of damage in average and plague years before control campaigns were mounted. Costs of not controlling an infestation would include the value of the crops lost plus resulting relief and rehabilitation costs, e.g., food aid and seeds for replanting.

When costs v. benefits are examined, the monetary costs of the 1986 through 1989 control program may not have yielded a favorable net return in terms of the amount and value of crops saved. USAID's mid-term evaluation of its AELGA project found that data was not available to assess the value of crops and livestock saved (99). Some evidence, however, shows that the value of production saved in 1986, generally did not equal or exceed the value of inputs received for treatment in five of the nine Sahelian countries (72). Overall, donor contributions of $40 million for control seem high compared to the estimated $46 million of production saved. These findings were based on the best available, but admittedly unreliable, national-level aggregate data. USAID's 1989 Programmatic Environmental Assessment of grasshopper/locust control incorporated the findings and underlying assumptions of this 1987 study. Thus, USAID accepted the conclusion that the costs of the control program in 1986, barely exceeded the value of the crops saved Furthermore, historical data show that increases in control rests do not necessarily result in decreases in crop losses. Data from earlier Desert Locust plagues show that average annual crop damage increased 175 percent between 1930 and 1955 even though control expenditures climbed an average of 600 percent (15).

The costs of control relative to the value of benefits is also affected by the efficiency of operations and the way that costs and benefits are defined in space and time. Inappropriate spraying and target selection increase the cost of control. Early treatment is costly if benefits are defined for local or national areas. Yet, early treatment may be considered economically efficient if it prevents a plague (95). In that case, estimated benefits increase because they accrue to a number of countries over a longer time period.

The cost-effectiveness of locust and grasshopper control programs has not been demonstrated convincingly. This is due, in part, to the scarcity of data, and that is understandable, given the constraints of data-gathering in vast, remote areas, the few people and other resources that national governments can devote to the task, and the emergency nature of the situation. No single organization is responsible for collecting the kind of data that would be required to provide a thorough evaluation of the costs and benefits of control operations. Groups have concentrated on implementing control operations without asking whether those efforts were, in fact, economically justified and without using part of their resources to collect data on crop losses and control costs. Without such data, sound policymaking is impossible.

After-the-fact cost/benefit analysis reinforces the impression that control programs are expensive and ineffective (95). Yet, this assessment may be unfair because cost/benefit analysis is more appropriately used to evaluate options before one is selected. Also, cost/benefit analysis assumes that money not put into one use would be available for other uses. This is not the case here because money available for disaster assistance is not necessarily available for other uses.

A number of issues, such as local knowledge and acceptance of the risks of control, are not well captured in cost/benefit analysis yet may have important implications for the effectiveness of programs (131), for the growth of institutions, and for U.S. interests (97). In addition, donors' responses to perceived emergencies do not follow a strictly economic rationale. This assumes, however, that: 1) locust and grasshopper outbreaks or upsurges are truly emergencies and 2) emergency responses are effective. These are questionable assumptions (95).

Certainly if control operations cannot be justified on the basis of monetary costs alone, it would be hard to justify such efforts based on broader definitions of effectiveness that account for additional costs (or hazards and risks) such as environmental and health hazards. For example, attempts to calculate the costs and benefits of current control programs have not estimated the real or potential costs of loss of beneficial organisms, onset of insect resistance, and general environmental contamination.

Regardless of debates about cost/benefit analysis, it remains clear that control costs in Africa can be reduced. Spraying efficiency can be improved. In addition, considerable room for improvement exists in determining provisional economic thresholds for making pesticide application decisions (95).

HEALTH AND THE ENVIRONMENT

Finding: Safe, environmentally sound use of insecticides was not ensured during the 1986 through 1989 grasshopper and locust control programs and human and environmental exposure were, at times, dangerously high. Application, storage, and disposal of insecticides were not monitored adequately, nor were the cumulative effects of other health and spraying programs taken into account.

Human Exposure

Evidence from a variety of sources suggests that direct and indirect human exposure to insecticides was sometimes dangerously high in recent campaigns. At least half of the respondents to OTA'S survey indicated that either accidental Poisoning of humans or adverse environmental impacts due to pesticide use had been detected. Frequent instances of contamination in ground spraying crews were observed in the Gambia, resulting in some poisonings (114). The AELGA mid-term evaluation cites a story of flies dropping on contact with a control technician even after he washed thoroughly (99). Insecticide poisoning was reported in Niger as a result of people eating treated locusts (99). Also, human poisoning occurred when "empty" pesticide containers were reused to store water or food (77).

Numerous pesticides, known to be toxic to grasshoppers and locusts at different formulations, rates of application, temperatures, etc., also constitute various levels of hazard to people, according to the U.N. World Health Organization (111):

- extremely hazardous (parathion),
- highly hazardous (aldrin, dichlorvos, dieldrin, DNOC),
- moderately hazardous (alphacypermethrin, bendiocarb, BHC (or HCH), carbaryl, carbosulfan, chlorpyrifos, cyhalothrin, cypermethrin, DDT, deltamethrin, diazinon, fenitrothion, fenvalerate, heptachlor, lindane, phoxim, propoxur, tralomethrin),
- slightly hazardous (acephate, malathion).

The health effects of insecticides can be acute or chronic, depending on the amount, extent, and duration of exposure, chemical concentration, and individual sensitivity. With sufficient exposure at sub-acute levels, some chemicals produce chronic health effects, including cancer and neurological and reproductive disorders. For example, aldrin, BHC, dieldrin, and lindane accumulate and remain in the human body for considerable periods of time, with the potential for chronic effects. USAID has prohibited the use of these persistent pesticides for health and environmental reasons since the late 1970s (43). The impact of long term exposure of entire populations in given areas to pesticides from a variety of agricultural and health spraying programs is largely undocumented. However, the fact that large numbers of **people may unknowingly experience subclinical, chronic changes without having been offered information or risk-reducing choices is worrisome** (95).

People can inhale or ingest insecticides directly or absorb these chemicals through their skin. Also, people can be exposed to insecticides indirectly through food or water supplies. For instance, locusts and grasshoppers are used as food in many African countries, especially by children, and they may ingest chemical residues by eating sprayed insects. However, the relative importance of locusts in people's diets is not known, nor do data seem to exist on the amount of pesticide residues on insects prepared as food.

People are likely to be exposed to significant levels of pesticide residues in other ways, also. USAID-funded field trials of six pesticides' residues in Sudan detected levels high enough that researchers recommended that bendiocarb should be limited to areas not used for agriculture or grazing, and that post-spray harvesting be restricted after fenithrothion and chlorpyrifos use (28). The dangers of exposure to insecticide residues in food and water supplies are known but were not routinely monitored as part of the spray campaigns in Africa. Insufficient attention was paid to the danger of contamination of already-scarce food, groundwater, and surface water in the recent campaigns. Insecticides that break down relatively quickly, such as malathion, are less likely to reach water sources than more persistent ones, such as lindane, but pesticide choice has not, by and large, been dictated by criteria such as potential environmental contamination.

Accidental exposure to pesticides can occur in a variety of ways: when spraying equipment malfunctions, when chemicals are stored with little regard to long term safety, or when containers are reused inappropriately (14). Technicians and herders have the highest probability of significant chemical exposure in locust and grasshopper control programs (27). Technicians are more likely than the general population to be aware of insecticides' hazards but few were trained to avoid them. Also, pesticides are often used in developing countries with inadequate safeguards for operators. Protective gear (goggles, face masks, respirators, boots, gloves and special protective clothing) is often unavailable. Or, its use may not be perceived as worth the discomfort in tropical climates. Soap and water for washing after handling or applying pesticides may be scarce.

Some contamination does occur, especially in areas where pesticides are not widely used and technicians are unfamiliar with them. Lack of training increases the risks of improper application and, thus, dangerous levels of exposure. Over-application of malathion occurred, for example, because control personnel mistakenly expected it to be a fast-acting insecticide and sprayed until insects dropped (99). While some training in safe pesticide use was developed during the recent campaigns, too few people participated for it to reach the people most in need.

Some believe that the public's exposure to pesticides used for locust control is likely to be quite small, especially because spraying often takes place over sparsely settled areas. However, USAID evaluators observed that "pesticide poisonin of humans and livestock is a more immediate lethal threat than the presence of locust swarms and hopper bands in isolated areas" (99). Widely dispersed pastoralists and subsistence farmers constitute a sizable portion of the population where locusts and grasshoppers occur, and their exposure to spraying is unrecorded. Although officials attempted towarn people inhabiting areas to be sprayed not to eat locusts, radio and print messages did not reach many seminomadic people and low-resource farmers (99).

Collecting age and gender disaggregated data is especially important in monitoring health impacts of pesticide spraying. Some chemical residues may affect nursing mothers, but not other people in the area.

Environmental Effects

Just as different insecticides pose various levels of hazard to humans, some insecticides, dosages, and methods of application are potentially more harmful to the environment than others (table 2-4). The extent of damage that insecticides inflict on the environment is not well-understood although certain chemicals seem to be preferable to others, given a region's environmental characteristics.

Aerial application of fenitrothion have been, reported to be phytotoxic to sorghum and reduce its yield (84). Malathion and carbaryl (like others) are highly toxic to insect pollinator. Some evidence suggests that the organophosphate pesticides generally have adverse effects on nontarget terrestrial organisms. For examp le, fenitrothion and diazinon can kill birds (58) and malathion applied to mallard eggs adversely affected hatchlings (42).

Several examples of harm to nontarget organisms and the environment were reported due to the recent campaigns in Africa. In Tunisia, substantial numbers of honeybee colonies were lost (50), damaging economically important apiculture and extending to the country's produce production because bees are important fruit tree pollinators. The most dramatic case of animal loss reported was the death of 30 sheep grazing in pesticide-contaminated areas (50). Also, chemical residues were found in the soil following spraying programs in Mali and Morocco (12). But no systematic program exists for monitoring the control program's effects on humans or the environment, so the extent of the damage is unknown. USAID's recent Dynamac-run field trials were expected to provide additional information on these types of environmental risks, but a recent evaluation found the design, implementation, and analysis of the trials faulty due to lack of baseline data, the insufficient involvement of the national crop protection services, and the absence of locusts in the Sudan trials (99).

"Many species may beat risk" based on potential impacts of the insecticides and given what is known about their effects from American and European research (95). The fenitrothion dosage recommended by FAO is near the threshold at which aerial applications cause immediate mortality to birds (93). Environmentally sensitive habitats (such as wetlands and lakes) are located in important control areas such as the outbreak areas of the African Migratory Locust and the Red Locust and certain of the Desert Locust's breeding areas. At least thus far, locust and grasshopper control has taken precedence over protecting environmentally sensitive areas.

Storage and Disposal

Many feel that inadequate pesticide storage facilities are an acute problem (46, 48, 101). Generally stores are poorly ventilated and need repair. For example, the 19 storage facilities in Somalia had leaking roofs, poor ventilation, and cracked earth floors (l).

Improperly stored pesticides may lose their effectiveness as well as pose a hazard. Undoubtedly some old stocks were used in the recent campaign without verifying whether ingredients were still active (37). And the leaks and spills that result from improper handling and storage can lead to major sources of contamination (95). For example, 25 200-liter barrels of malathion were badly dented, some were leaking, and they were stored in direct sunlight at a site in Algeria (89). A mound of approximately 2,000 five-liter cans of dimethoate have corroded and leaked outside of Khartoum, Sudan (49) and all of Sudan's provincial stores needed complete overhaul when they were examined in the mid-1980s (101). Twenty-six

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Table 2-4—Toxicity of Various Pesticides to Non-Target Organisms

Chemical	Persistence	Bioaccumulation	Birds	Mammals	Fish	Aquatic invertebrates
Carbaryl	L	L-M	L	L	L	L
Diazinon	M	M	M-H	L	M	H
Dieldrin	H	H	H	H	H	M
Fenitrothion	L	M	H	L	L[a]	H
Lindane	M-H	H	M-H	M	M	M
Malathion	L	L	M	L-M	L	L
Propoxur	L-M	L-M	L-M	M	L	H
Acephate	L	L	L	L	L	L
Bendiocarb	M	M	M	M	M	M
Chlorpyrifos	M-H	M-H	--	M	L-M	H
Cypermethrin	M-H	H[b]		L	H	H
Lambda-cyhalothrin	M	H[b]	L	H	H	H
Tralomethrin	M	H[b]	L	L	H	H

KEY: L = low
M = medium
H = high

NOTES:
[a] Fenitrothion is moderately toxic t. fish, Foster L. Mayer, Jr. and Mark R. Ellersieck, *Manual of Acute Toxicity: Interpretation and Data Base for 410 Chemicals and 66 Species of Freshwater Fish*, Resource Publication 160 (Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, 1986), pp. 224-230.
[b] Based on log P.

SOURCE: TAMS, Inc. and the Consortium for International Crop protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment*, Executive Summary, contractor report prepared for the U.S. Agency for International Development, March 1989, p. EXSUM-25.

metric tons of old fenitrothion, dimethoate, and heptachlor formed a toxic lake outside the Desert Locust Control Center in North Yemen (48).

Many experts find that improved storage facilities are urgently needed, along with the training to manage them, because sizable stocks of insecticides, including the more hazardous organochlorines, exist in a number of countries. For example, 60,000 liters of dieldrin are stored in Mali, 56,000 liters in Mauritania, 35,500 liters in Somalia, 30,000 liters in Ethiopia, and21,000 liters in Niger (13). In some cases, lindane and dieldrin are kept by the national crop protection services to use as a last resort only if other insecticides are not available or if infestations reach critical levels.

Suitable disposal facilities are lacking for these and other pesticides and their containers. As a result, only a portion are destroyed following recommended procedures and excess stocks and containers may be discarded in ways that make human, land, or water contamination virtually certain. Many of the estimated 10,000 200-liter metal drums used in the recent campaign probably have been used to store water, fuel, or grain or for a variety of other purposes (77). Disposal procedures are highly variable among countries and various donors also assess the situation differently.

In some cases, donors contribute to the storage and disposal problems. Often, donated insecticides are inadequately packaged for ship-

ping, storage, and use in the tropics, with labeled instructions not understandable to the persons handling them. For example, Kenya and North Yemen received dimethoate in leaking drums in the late 1970s and were unable to use it. Now, the old stocks remain, creating a disposal problem (47,48).

Cumulative Effects

Pesticide use for locust and grasshopper control programs should be put in the context of total developing country pesticide use. Chemicals applied for locust and grasshopper control, while substantial, may be overshadowed by broad-scale applications for other agricultural purposes and for disease control. The amounts used for such different purposes vary considerably, making it difficult to sort out the potential impacts of each. Generally, more pesticides are used in agriculture than for health-related vector control. For example, estimates exist that Sudan uses 100 times more pesticide on cotton crops than in malaria control programs (95). Many of the same chemicals are used in both programs, as well as for grasshopper and locust control. For example, dieldrin, DDT, malathion, fenitrothion and propoxur are, or have been, used for malaria control (14) and dieldrin for tsetse fly control (34). Some fear that the overlap of various spraying programs may lead to unanticipated human health effects, increases in resistant disease vectors, or greater likelihood of certain epidemics (14, 95).

Pesticide use seems to be on the upswing. The current shift from persistent organochlorines to organophosphate and carbamate compounds requires more frequent application. With the amount of arable land available for new cultivation diminishing, many African countries can only increase their agricultural production through more intensive agriculture. Increased use of pesticides is often a key strategy and African farmers are using increased amounts of pesticides each year (loo).

The Special Case of Dieldrin

Of those pesticides used for locust and grasshopper control, dieldrin's use is the most debated, with the United States at odds with FAO and French officials. In the United States, concerns are over the potentially "fearsome" (95) negative effects of dieldrin's widespread and long-term use in locust and grasshopper programs.

European and U.S. studies, beginning in the 1960s, found substantial traces of dieldrin in human tissue. Problems of environmental persistence and negative effects on nontarget species also surfaced. As a result, EPA canceled most dieldrin uses in the United States (133) and a number of European countries followed suit (53).

Currently, USAID gives preference to short-lived, nonpersistent materials and to chemicals having EPA registration, particularly if registered for the intended use. Dieldrin meets neither criterion. Therefore, USAID supports no efforts in which dieldrin is used. In large part, this restriction has led other donors and African governments to abandon use of dieldrin in grasshopper and locust control.

On the other hand, FAO (104) claims that the severity of the 1988 desert locust infestation is partly attributable to donors' unwillingness to supply dieldrin in 1987. As a result, FAO contends, swarms escaped on two major occasions from restricted breeding areas, and gave rapid rise to the expansion of the plague.

> **While the United States may regard [the effective withdrawal of the use of dieldrin] as a victory, the fact is that Desert Locust hopper control using nonpersistent pesticides will be much more time-consuming, must less effective, and much more expensive than it was with dieldrin. Our prediction is that this will substantially increase the likelihood of seasonal upsurges developing into major upsurges and plagues, at least until such time as some of the postulated alternatives prove effective. (13)**

French officials, relying on recommendations of a French research agency (PRIFAS), also disagree with the U.S. position to withhold dieldrin. **However, as African countries become more aware of dieldrin's harmful effects, they have become more supportive of the U.S. position, even impounding donated stocks of dieldrin. For example, Cape Verde now bans all pesticides that are prohibited in the United States (99).**

Dieldrin is no longer produced in sizable quantities, except perhaps in Libya and India (121), so continuing debates regarding its use center on whether existing stocks should be destroyed or used in remote areas with special guidance. The

most recent estimate is 380,000 liters stored in West Africa(77). Currently, FAO policy is that use of available stocks is left to countries in which they are located, as specified in the International Code of Conduct on the Use and Distribution of Pesticides.

INSTITUTIONAL AND POLITICAL ASPECTS OF CONTROL

Finding: Most institutions–whether African national or regional or donor-am not equipped to deal with grasshopper, locust, or other pest problems on a long-term basis. Development needs are often sacrificed in favor of crisis management. Disputes within, between, and among African countries and donors constrain the effectiveness of short-term emergency programs and longer-term preventive ones.

Institutional Factors

A variety of institutional problems related to pest management are commonplace in Africa. Many countries lack the resources–operational aircraft, vehicles, communications and spraying equipment, and fuel–to deal with pests. Also, many lack the legal structure for regulating import, application, and disposal of pesticides. Few have medical facilities to treat pesticide poisoning or extension programs to train farmers how to use pesticides properly. Most countries lack personnel trained to detect environmental damage from insecticide use, to assess economics of locust control, and the effects of changing land use, etc. Coordination between agencies is difficult to achieve, and many other agricultural problems compete for scarce research attention.

These conditions are true for many countries, but wide variations exist also. Generally, the northwest African governments have more well-developed infrastructure, more trained personnel, and far more resources than Sahelian governments.

Teng (96) documented shortcomings of African national plant-protection services m 15 tropical West and Central African countries (table 2-5). Some problems were common to most public institutions, such as cumbersome decisionmaking and staff reductions accompanying policy reforms. But others were specific to these services. Major forms of plant protection infrastructure are not in place in many African countries, for example, only five African countries have pesticide laws (%).

A variety of additional factors affect locust and grasshopper programs specifically, especially due to the episodic nature of upsurges. Much of the infrastructure built for grasshopper and locust research and control gradually lapsed after the last major Desert Locust plague ended in 1%3. Many European experts with valuable field experience gained in earlier campaigns had retired or died without training replacements. As a result, little institutional memory remained when the current upsurge began and the new generation of entomologists had not faced problems of this kind or scale before. Thus, existing African and donor infrastructure was incapable of handling this emergency effort well, let alone mounting a longer-term approach that would emphasize upsurge prevention.

An examination of these specific problems was made in Chad, highlighting problems of imprecise data on the extent of the problem, vehicle breakdown, poor training, shortage of survey materials and other equipment, lack of preparation before the rainy season, inaccurate treatment figures, and no records of undesirable environmental effects (11). Donor-supported programs may not be sustainable given such conditions. For example, USAID's 1987 training-of-trainer efforts broke down when Sahelian governments did not allocate sufficient funds for travel costs and other expenses needed for these newly trained personnel to train field-level staff, in turn (95).

National crop protection services benefit from the international support that follows a disaster and national governments may exaggerate the locust and grasshopper problem in an effort to obtain resources. Often crop protection services rely on these funds for maintaining their staff, vehicles, and spraying and communication equipment. Governments take the opportunity to restock imported insecticides that could be used against insects other than grasshoppers and locusts (114). Even under the best of circumstances, locusts and grasshoppers are difficult to count. For example, hopper bands in remote areas are difficult to detect and maybe undercounted, but migrating swarms are sighted in many areas and are easily overcounted. FAO, like other U.N. agencies, compiles information from individual countries rather than collecting independent data. With no means to verify data supplied by individual

Table 2-5-Strengths of Fifteen West and Central African Countries[a] in Various Areas of Plant Protection

Area of plant protection	Percent of Countries in category		
	Good	Moderate	Poor
Plant protection personnel	7	40	46
Pest control equipment	0	47	47
Support facilities	0	13	80
Plant protection laboratories	0	47	47
Pest diagnostic laboratories	0	47	47
Plant quarantine buildings, equipment	7	40	40
Pesticides available locally	0	43	20
Plant protection service	7	20	40
Agricultural schools, training facility	7	66	20
Specialized plant protection curriculum	7	33	53
Institutionalized research	7	53	20
On-farm, applied research	0	13	74
Pest lists	13	47	33
Pest distribution knowledge	0	47	40
Pest biology knowledge	7	7	13
Economic loss knowledge	0	27	40
Pest control knowledge	0	20	80
Overall strength:			
Extension	7	40	40
Research	20	54	13
Training	7	46	40

NOTE: [a]Countries in survey were Benin, Cameroon, Central African Republic, Congo, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Nigeria, Sierra Leone, Togo, and Zaire

SOURCE: P.S. Teng, "Plant Protection Systems in West and Central Africa-A Situation Analysis," unpublished report to U.N. Food and Agriculture Organization's Plant Protection Service (Rome, FAO) August 1985.

countries, neither technical errors nor institutional incentives for over-stating can be balanced.

In sub-Saharan Africa, locust and grasshopper control is unlikely to ever be the sole responsibility of national crop protection services or other national groups, even under the best of circumstances. First, many locust and grasshopper breeding areas, especially that of the Desert Locust, are in remote and uncultivated areas that the national crop protection services have neither the resources nor clear mandate to reach. Also, extensive seasonal migration patterns mean that insects originating in one country threaten crops in another. The long recession periods between insect upsurges mean plans can go untested for long periods of time and scarce national resources can be diverted to other efforts.

The regional African institutions in the Sahel, established to pool scarce technical resources and to accommodate the regional nature of these migratory pests, also are beset with funding and management problems. In addition, they are subject to conflicting and changing approaches of member states and donors. For example, institutional weaknesses of the Permanent Interstate Committee for Drought Control (CILSS), a regional intergovernmental organization in the Sahel, were cited as a major reason for the disappointing performance of the regional integrated pest management project of the 1970s (128).

Similarly, shortcomings in donor programs have been documented. Donors and insecticide manufacturers were unprepared for the recent upsurges, like their African counterparts. As a result, technologies selected for the recent control effort did not differ significantly from those used in the early 1960s. Newer insecticides and containers had not been tested in Africa, and the latter proved inadequate in the African setting. USAID had little scientific capacity to carry out a long-term, technically sound locust and grasshopper control program. U.S. entomologists were brought on as temporary consultants, interns, or borrowed from other agencies. Few had field experience dealing with locust and grasshopper upsurges in Africa. Fewer spoke French, and most of the area affected in the recent upsurges is Francophone.

Locust and grasshopper programs became crisis management, in part, because of this lack of preparedness. And, the high costs of crisis management are nearly unanimously cited as a problem (99). Generally, emergency assistance has not been done with an eye to future development needs; nor has development assistance usually incorporated disaster mitigation (68). The locust and grasshopper programs were no exception.

Developmental goals of locust and grasshopper programs are not well defined and tend to be overshadowed by the attention to the emergency effort. Emphasis on crisis management can narrow other opportunities due to direct competition for funds within donors' budgets, shifts to more readily funded short-term research, etc. For example, USAID mission buy-ins for emergency activities reduced the amount available for long-term development projects, and particularly adversely affected countries with small USAID programs (99). Similarly, USAID-funded training programs were suspended in 1988 because resources were redirected to emergency control. A related result was confusion over roles and responsibilities, especially within USAID missions. For example, the USAID missions' locust and grasshopper staff performed the duties of other staff, often for the sake of expediency (114). Generally, an emphasis on short-term emergency management has also meant that donors and African agencies missed opportunities to tap local resources such as people's indigenous knowledge of pest biology (57).

Crisis operations do not lend themselves well to institution-building and the present campaign was no exception. For example, due to the lack of preparedness of the African regional institutions such as the Joint Locust and Bird Control Organization(OCLALAV), expatriates under the auspices of FAO ran the control operations, especially aerial spraying, in much of the Sahel. This parallel organization resulted in a technically effective control program that, inadvertently, further undermined OCLALAV (99).

Differences in strategy and tactics among donors led to confusion among African officials regarding technical approaches and to costly delays and duplication of effort. Also, differences increased pressure on the African officials who dealt with the oft-conflicting requirements while attempting to manage national campaigns. For example, field personnel had to be trained in the proper use and maintenance of several different kinds of spraying equipment for the same use.

Donors agree that emergency relief has substantial popular appeal. Further, USAID and FAO agree that lack of funds constrains them from implementing key components of a more preventive approach, e.g., long-term institution building of crop protection services, providing equipment and training for surveillance and monitoring of insects, pre-positioning of pesticides to reduce costly air freight expenses, and setting up mobile units to survey and control locusts in "strategic" breeding areas in remote areas.

These institutional perspectives, combined with the lack of important information, help explain the tendency to exaggerate locust and grasshopper problems and to take a crisis management approach. Acting in one's self-interest is appropriate, and acting in the interest of one's organization is normal. The common good, however, requires balancing individual self-interest and the interests of others. To do this, leaders need an accurate view of overall problems. Sometimes this view was lost during the recent campaign. For example, frequent assertions by representatives of FAO, USAID, and African governments that the recent upsurges were the worst locust lague ever recorded are not documented (see igure 1-3).

The Politics of Locusts and Grasshoppers

There are those who claim that locusts and grasshoppers are primarily "political pests" because of political pressure to mount a control campaign. Some of this pssure is readily understandable: locusts are highly visible, swarms can create panic, they can cause severe damage in localized areas, and large-scale aerial spraying is more easily undertaken and provides more visible results than alternatives.

Memories of devastating incidents caused by Desert Locusts and other swarming insects in the 1940s and 1950s can lead political leaders to respond urgently to the perceived threat of disaster. This, combined with popular perceptions that these insects cause severe crop damage, increases political pressure to mount an aggressive control effort. For example, during the recent upsurge, Moroccans and others often referred to the near-total damage caused in 1954 and 1955 by Desert Locusts in the Seuss Valley where orange trees are the most valuable agricultural product. This damage was estimated at $14 million in 1954 dollars (13); at least 10 percent of Morocco's farmland was affected mostly in the south and Seuss Valley (115). Moroccans feared that the insects would cause similar serious damage even though swarms of the Desert Locust came to the Seuss Valley in 29 of the 55 years up to 1968 (79) without causing such damage. A crisis mentality and prception of imminent disaster can lead people to act hastily and may account for some of the carelessness in pesticide use and over-spraying that occurred in the recent campaign (99).

Emergency Control programs are popular, like other disaster assistance efforts. Of all kinds of foreign aid programs, Americans support disaster relief the most; three quarters of Americans surveyed recently gave it top priority (23). Thus, donors, like their African counterparts, come under political pressure from legislatures and the public to act during locust and grasshopper upsurges.

Also, donors do not want to be left out or appear unresponsive when African governments request disaster assistance. USAID, like the national crop protection services, benefits from support garnered during a disaster. USAID officials can readily justify requests to Congress for additional funds to stop a plague of locusts, and those funds generally are forthcoming.

Other vested interests come into play during locust and grasshopper campaigns, such as preferences for bilateral over multilateral programs, tied aid requirements, or funding programs in certain countries but not others for political reasons. These factors often override decisionmaking based on technical considerations. For example, some advocate sharply curtailing fenitrothion's use because of potential environmental damage. Political factors are likely to enter into such a decision-whether made by USAID, FAO, or African Governments. The United States would be seen as advocating U.S.-manufactured alternatives (American Cyanamid produces malathion and Union Carbide, carbaryl) to the Japanese- and German-produced fenitrothion.

The most public differences among donors in this recent campaign related to pesticide selection and application methods. However, many less visible differences existed regarding overall development goals and strategies. For example, donors disagreed on the relative importance of increasing net agricultural production, increasing yield, increasing farm income, building democratic institutions, developing a more equitable distribution of power, or supporting sustainable agriculture. Different donors also assessed the locust and grasshopper situation differently and proposed different control strategies-e. g., the highest priority sites for treatment, whether ground or aerial spraying should be done, what types of aircraft should be used, whether or not to emphasize training or environmental monitoring, etc. Also, donor agencies disagreed internally on many of these items.

Finally, coordinating a regional response is made more complicated by political problems within and between affected countries. Civil strife and wars in Ethiopia, Sudan, Chad, and Mauritania prevented survey and control campaigns from reaching locust breeding areas before swarms grew large and began migrating. For example, in 1987 the Ethiopian Government did not allow the Desert Locust Control Organization for Eastern Africa and the Red Cross to conduct survey and control efforts in the Tigre, Eritrea, and Wolla provinces due to civil war. These are seasonal Desert Locust breeding areas where the upsurge might have been contained. Nor was the national crop protection service able to carry out control efforts in these areas, although the Eritrean Liberation Front trained and equipped its members to conduct effective ground control operations (19).

Land mines in the Western Sahara precluded ground survey and control efforts; a USAID-contracted spray plane was downed by a Polisario missile there, killing the five on board. Also, longstanding border disputes constrained cooperation between countries. Morocco, frustrated by ineffective control efforts in Sahelian countries that resulted in swarms invading the southern part of Morocco, proposed sending their survey and control teams into Mauritania in military-like missions.

Chapter 3

Strategies for the Future

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Chapter 3

Strategies for the Future

OTA's analysis found that the 1986-89 locust and grasshopper control campaigns in Africa were based on questionable premises, with partially effective to ineffective implementation. Yet, some things worked well and U.S. efforts contributed to these successes.

WHAT USAID DID WELL

Finding: USAID made commendable attempts: 1) to coordinate its efforts with other U.S. agencies, foreign donors, and African officials;* 2) to *provide training for Africans and U.S. personnel; and 3) to highlight issues of sound insecticide choice, storage, application, and disposal. Overall, the international control campaign lacked these characteristics, however. USAID did prevail successfully against the use of dieldrin.

Promoting Internal and External Coordination

The U.S. Agency for International Development (USAID) coordinated its work successfully within USAID and with other U.S. Government agencies involved in the campaigns despite formidable institutional constraints. The Desert Locust Task Force, established within USAID's Office of Foreign Disaster Assistance (OFDA), was one of the most effective means of coordination within the U.S. Government. From July 1988 through June 1989, the Task Force held weekly meetings to share information, assign responsibility for implementing activities, and coordinate efforts.

Also, OFDA brought together people representing a variety of U.S. Departments and other organizations to review results from the previous year's efforts, to identify lessons learned, and to plan more effective future control. OFDA sponsored two workshops for Task Force members from Washington, DC, USAID mission staff from Africa, and outside experts. First, the U.S. Forest Service's Disaster Assistance Support Program managed a 3-day workshop in January 1988 in Harpers Ferry, West Virginia, for 69 officials, mostly from the U.S. Government, to evaluate the 1986 and 1987 campaigns and provide direction for a staff guidebook on locust and grasshopper programs. Then, 32 participants took part in a 4-day, February 1989, workshop in Dakar, Senegal; they reviewed each country's 1988 campaign and were introduced to the finalized USAID guidebook.

This 1989 ***Locust/Grasshopper Management Operations Guidebook is*** well-prepared and thorough, for the most part. It provides a comprehensive overview of USAID's policies regarding locust and grasshopper control, includes useful background information on the insects' biology and behavior, sets forth the rationale and procedures for mounting a control operation, provides details on conducting insect surveys and selecting appropriate control techniques, and includes helpful supplementary information (e.g., pesticide-use guidelines, procurement procedures).

OTA expects that the Guidebook will contribute to a more expert, consistent, and coordinated U.S. response to grasshopper and locust problems in the future. If used effectively, the Guidebook could achieve its purpose: "... to assist Missions to assess, prepare for, and organize locust/grasshopper control programs on an emergency and non-emergency basis" (118, p. I-2).

The Guidebook is the most up-to-date operational source for selecting insecticides for U.S.-funded work and lists a number of selection considerations. However, the database on insecticides constantly changes. For example, the U.N. World Health Organization's Hazard Classification, revised every 2 years, now has different ratings for approximately one-fourth of the pesticides included in the 1989 Guidebook. USAID is preparing Country Supplemental Environmental Assessments in 1990, with technical assistance from the U.S. Environmental Protection Agency (EPA), to apply the continent-wide Programmatic Environmental Assessment to the individual countries planning to use insecticides against grasshoppers and locusts. This process, which aims to make more site-specific plans, could allow updated information on different chemical products to be incorporated in the supplemental assessments simultaneously. However, these supplemental assessments also will need to be revised periodically to remain current.

USAID actively promoted coordination among other donors and African governments, and agreement exists that coordination and collaboration among countries increased as the recent campaigns progressed. For example, representatives of USAID or the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service attended perhaps a dozen meetings sponsored by the U.N. Food and Agriculture Organization (FAO) to share information and plan future strategy. USAID funded FAO's Emergency Centre for Locust Operations (ECLO), the worldwide coordination site for locust and grasshopper control operations, and USAID staff provided ECLO with data on insect populations and U.S. control efforts. The Bureau for Science and Technology participated in the World Bank's Special Program for African Agricultural Research on locusts.

USAID required that recipient countries have an operational Country Coordinating Committee, composed of representatives from relevant government and donor organizations, before U.S. emergency funds were released. USAID mission staff participated in these committees and also maintained direct contact with the national crop protection services and other African agencies involved in control.

Providing Training

USAID provided training for its own personnel and African officials through workshops and the provision of technical assistance. Additionally, the United States funded training programs for Africans, conducted by FAO and regional organizations. For example, FAO trained Sahelian national crop protection personnel in locust surveillance and another group, Application of Agrometeorology and Hydrology for the Sahel (AGRHYMET) conducted an annual short course for African officials on using "greenness maps." This training and technical assistance, together with the provision of equipment and supplies, undoubtable strengthened the capacity of national institutions to mount future locust/grasshopper survey and control programs and to deal with other agricultural problems.

USAID conducted 10 training workshops from 1987 through late 1989 with a total of approximately 150 participants. One early workshop on how to plan and manage aerial spraying operations was attended by Africans from Senegal, Gambia, Niger, and Sudan. From April through June 1989, three regional workshops were held on: 1) aerial and ground ultra-low volume (ULV) application, 2) training extension workers to use new teaching materials on pesticide use, and 3) human health impacts of pesticide application (121). A February 1990 conference on pesticide disposal, held in Niamey, Niger, attracted 58 participants from 15 West African countries and international organizations such as Earthwatch and Greenpeace. Action plans were drawn up for each country. Other workshops planned for 1990 are on identification of immature Sahelian grasshoppers and crop loss assessment.

USAID developed some useful materials for its training efforts. For example, the ***Pesticide Users Guide,*** prepared in four languages for African extension agents, details how to conduct pest surveys, plan insecticide applications, and apply, transport, store, and dispose of pesticides. In addition, USAID funded publication of a field manual for identifying immature grasshoppers (51).

USAID attempted to increase its own technical capacity by borrowing experts from other U.S. agencies and hiring consultants from universities and private firms. An effort was made to pair senior and junior entomologists on technical assistance teams to increase the pool of expertise available in the future. USAID encouraged participation of African officials on the several dozen U.S. technical assistance teams sent to Africa. This practice imparts on-the-job training—for those U.S. scientists unfamiliar with African conditions as well as for African experts unfamiliar with some recent pest management technologies.

Advocating Sound Insecticide Use

USAID advocated safe and sound insecticide use throughout the 1986-89 campaign and enforced its relevant environmental policies. Its greatest success was persuading other donors and African governments not to use dieldrin, even though many African countries had existing dieldrin stocks and FAO and France urged its use. With encouragement from USAID, FAO is taking inventory of existing stocks of dieldrin, beginning a study of potential environmental risks of dieldrin

use in areas where the Desert Locust is present, and intends to develop a plan for use or destruction of dieldrin based on these findings (104). USAID, too, has compiled some information on stocks of dieldrin (99) and sent EPA representatives to advise African officials on storage and disposal of surpluses.

USAID's efforts also increased awareness in Africa of the potential dangers of the persistent organochlorines and helped reduce the use of benzene hexachloride (BHC) and lindane. USAID encouraged the use of less toxic chemicals and, to a limited extent, tested new insecticides for locust and grasshopper control under African conditions.

USAID **promoted increased efficiency in some spray operations, for example, by prepositioning insecticides in Africa to reduce high air freight costs. By supporting application of satellite remote sensing to locust surveillance and funding research on alternative control methods,** USAID **began to lay the groundwork for reduced reliance on spraying as the only available response to locust and grasshopper upsurges.**

USAID included safety concerns in its technical assistance and training programs, e.g., by providing protective clothing for spray operators. USAID claims it was the first to introduce cholinesterase testing into locust control programs in Africa. Moroccan applicators were tested before, during, and after spraying in 1988 and 1989 to determine if the enzyme cholinesterase had been suppressed by pesticides (51).

Also, USAID exhibited concern about the environmental effects of control programs, in particular by preparing environmental assessments for Morocco, Tunisia, and all of Africa and Asia affected. Since mid-1989, USAID has been designing ways to implement the 38 recommendations of the Programmatic Environmental Assessment (app. E). Technical assistance teams are assisting African nations on the safe disposal of empty containers and surplus insecticides now that widespread spraying is unnecessary.

USAID is seen as among the strictest donors regarding safe pesticide disposal and is planning to take stronger measures in the future. Its operational Guidebook contains directions for storing, packaging, labeling and disposing of pesticides and empty containers. An annex contains a copy of FAO's 1985 ***Guidelines for the Disposal of Waste Pesticide and Pesticide Containers on the Farm*** **that details physical, chemical, and biological disposal methods. Some other donors have similar interests and a recent workshop on disposal of obsolete pesticides and empty containers in Niamey demonstrated African concern as well.**

In short, USAID **succeeded in almost eliminating the use of the most hazardous chemical, dieldrin, and identified some lessons learned for improved strategies and tactics for future programs. The overall locust campaign, however, demonstrated the need for more coordinated action, far more training, better understanding of locust and grasshopper dynamics and effects on crop yields, and improved control methods. For example, the new** *Locust/Grasshopper Management Operations Guidebook* **fails to discuss the debate over the relative roles of control in insect declines;** USAID's **1988 training sessions were sidelined when its resources were redirected to spraying activities;** USAID's **training and technical assistance reached only a few Africans; and, in some cases,** USAID **did not convince Africans of less toxic chemicals' effectiveness.**

Admittedly, USAID is only one important actor, having provided about one-fifth of donor funding for recent control campaigns. Thus, USAID has limited responsibility for the failures of recent campaigns, as well as their successes.

HOW TO DO BETTER NEXT TIME

Finding: Donors and African governments cannot afford to fund expensive control campaigns without addressing fundamental questions regarding goals and implementation. Now is the time to find methods that contribute to long-term development, redouble preventive efforts, and decide what actions will be most effective during the next upsurge.

Doing **better in the future, during recessions and upsurges of these insects, revolves a reexamination of fundamental questions regarding who should do what, and when, where, how, and why it should be done. These are broad policy questions encompassing all aspects of control programs. For example, which insects should be included in programs (individual pests or groups** of similar pests), where control should be mounted ("strategic" areas, breeding sites, or anywhere), when control should be undertaken (when a plague threatens, when swarms threaten crops, or whenever insects become gregarious), why control is needed (e.g., to stop plagues, save crops, or prevent famine) and how control is best done (e.g., aerial or ground spraying, four- or single-engine planes or helicopters).

Control organizations, host governments, and donors have the responsibility to [illegible] these questions. Here, OTA identifies some elements of the discussion and notes that resolution of these issues should be attempted now that upsurges have subsided for a time. The roles of various groups–who should do what–also need to be clarified. This question is addressed in chapter 4.

Further discussion and clarification are especially needed regarding the goals of the control programs and indicators to measure their results within specified times. Do the programs aim to prevent plagues, stop plagues, protect crops, or end famine? Different goals imply different strategies, action plans, and evaluation criteria.

The Feasibility and Price of Prevention

The FAO and USAID officials responsible for grasshopper and locust control programs maintain that knowledge is available that, if properly applied, could prevent future plagues of locusts and grasshoppers (12, 95, 121). Plague prevention has consisted, since the 1960s, of making surveys in seasonal breeding areas and controlling any already-gregarious resects or populations becoming gregarious (70). Certainly, the feasibility of prevention steadily increases as additional countries agree to participate in such an approach during recessions; as breeding areas are more clearly identified; as improved methods are developed for forecasting the rise and movement of insect populations, weather systems, and plant cover; and as more effective, carefully aimed control operations are mounted. However, some factors that contribute to plagues are unresolvable by existing technologies or largely beyond the control of donors. These constraints include the unpredictability of weather and disputes within and between countries. Also, wide-scale implementation of what is known, e.g., about effective spraying, is often exceedingly difficult under actual conditions. Thus, OTA questions whether donors and affected countries can prevent upsurges and plagues, although that goal is laudable and deserves to be foremost.

FAO finds that:

> . . . although there is a rational strategy for the prevention of desert locust plagues, and tactics and techniques have been evolved to implement that strategy, circumstances can still combine to lead to the threat of the development of a new major plague. Furthermore such combinations of circumstances, and **in particular sequences of widespread heavy rain, cannot yet be forecast**

and concluded that:

> . . . local outbreaks capable of leading to major upsurges are likely to be a recurrent but intermittent feature of Desert Locust population dynamics. . . (81, cited in 13).

The preventive strategy FAO and USAID advocate thus requires a certain amount of continuing monitoring and control. Usually, that has not been done between upsurges. FAO and USAID officials are requesting funds for applying this strategy now with the explicit objective of preventing future outbreaks from developing into plagues.

They, like others, assume that plague prevention costs less than plague control. This seems correct intuitively but it has yet to be proven. Donor costs of the 1986-89 control campaign, principally against the Desert Locust and Senegalese Grasshopper, were $275 million. In 1988, representatives from several governments met in Fez, Morocco and approved plans for a multinational ongoing survey and control operation to monitor the Desert Locust in its remote Sahelian breeding areas. This International Desert Locust Task Force, with 5 main units and 13 sub-units in strategic areas, carried a $77.4 million price tag. As the plague subsided, the estimate for Phase I in 1989 was revised down to $3.5 million (106). Thus, the cost of maintaining these mobile units is far less than the cost of the recent control campaign in an equivalent period. However, the costs of plague prevention v. control should be calculated over a longer time period from a broader base, e.g., perhaps including costs for monitoring and controlling other grasshoppers and locusts and the related expenses of the national crop protection services.

FAO proposed recently a 5-year regional preventive Desert Locust control program for the 8 countries of Maghreb and the Sahel. FAO asserts that control measures in a generalized invasion would cost, in 1 year, what preventive control activities would cost in 15 to 20 years. FAO anticipates that this preventive program would cost $6 million to $8 million per year (108,109) and result in less insecticide use over a smaller area, e.g., 50,000 to 100,000 ha per year sprayed compared to the 15 million ha treated in 1987/88 (108). The availability of funding for such a broad international program has not yet been determined. Even if the preventive approaches advocated by FAO, USAID, and other officials were fully funded, it seems likely that emergency efforts would still be needed when the insects escape strategic control efforts.

Shifting to a preventive approach first requires a reorientation of thinking by African and donor policymakers, followed by corresponding changes in programs and financing. Crises mobilize attention and resources: emergency locust and grasshopper programs garner far more policy interest than long-term efforts, such as integrated pest management (IPM). Africans favored faster-acting insecticides. Emergency spraying operations fit within what some find is a "cowboy" mentality among U.S. officials: a tendency to promote large interventions and quick solutions. For example, U.S. officials emphasized use of four-engine planes while FAO and other donors preferred smaller planes. Thus, preventive approaches present psychological as well as technical challenges and their implementation would require attitudinal shifts and technical training within USAID, among other donors, within African countries, and in Congress.

Integrating Emergency Control Programs Into Long-Term Development

Donor groups often classify their activities as relief or development focussed. Generally, relief activities are short-term and address symptoms or consequences of deeply rooted problems. They can include actual control efforts and other activities to help people recover from losses, e.g., providing food to areas where locusts have destroyed crops, or providing seeds for replanting. Some also describe activities that help recipients recover from control programs (e.g., destruction of pesticide containers, disposal of surplus stocks, testing operators for over-exposure to insecticides) as "relief and rehabilitation." Development activities, in contrast, tend to deal with the underlying causes of problems and are necessarily longer term. For example, entomological research to develop safer or more effective control methods and efforts to prevent locust or grasshopper upsurges would be development activities.

Individuals and organizations generally concentrate their efforts on one approach or the other because of the difficulties of combining the two. Some relief efforts incorporate development objectives better than others: e.g., providing seeds rather than food aid, and training farmer brigades to conduct local survey and control programs rather than replacing local efforts with expatriate-run operations. Some relief programs can hamper development efforts. For example, food aid has long been criticized as lessening incentives for small farmer production although this is not always the case.

The U.S. foreign assistance mandate encompasses both relief and development programs. However, the recent grasshopper and locust control programs seem overweighted by short-term emergency responses despite the well-known weaknesses of crisis management. Nearly all U.S. funds for locust and grasshopper programs in fiscal years 1986 and 1987 were OFDA funds (table 1-3) and 58 percent of the Africa Emergency Locust/Grasshopper Assistance (AELGA) project's budget for fiscal years 1988 through 1990 was allocated to emergency assistance (chemicals, equipment, and short-term technical assistance) v. 42 percent for development assistance (research, training, and institutional support) (99). Respondents to OTA'S survey agreed that crisis management (e.g., spraying programs) was the major type of activity undertaken in recent campaigns (table 3-1). Most noted the need for a decrease in crisis management per se and an increase in both preventive measures and specific types of relief, although they did not advocate decreasing the overall total amount of resources (10). Their analysis agrees with that of others (e.g., 95).

The farmers and herders who are the intended beneficiaries of donors' programs do not distinguish between crisis management, subsequent relief activities, and long-term development assis-

Table 3-1-OTA Survey Respondents: Percent of Current and Ideal Locust Efforts Focused on Crisis, Relief, and Prevention (N = 25)

	Current effort		Ideal effort	
	Median	(Range)	Median	(Range)
Crisis	90%	(25 - 100%)	50%	(O - 80%)
Relief	5%	(o - 30%)	10%	(o - 50%)
Prevention	1%	(O - 32%)	30%	(5 - 100%)

SOURCE: Dale G. Bottrell. 'locusts in Africa and the Middle East: Summary of Response% to OTA Questionnaire," contractor report prepared for the Office of Technology Assessment, May 1989.

tance. For them, locusts and grassho pers represent one more crisis in lives that are full of crises, each further narrowing their options and contributing to the downward spiral of poverty (20). Likewise, locusts and grasshoppers are only two of many types of pests that threaten their crops. For long-term development to succeed, it seems that far more attention must be paid to how pest problems interact with other difficulties and to the development implications of grasshopper and locust control.

In this context, plant protection needs to be viewed as a process that integrates local, national, regional, and international components. Many farmers and herders have few options for controlling large upsurges of locusts and grasshoppers when prevention fails. They may need assistance during that difficult, but brief, period in which their losses can be severe. Thus, short-term relief may be needed locally, either to prevent crop damage or to enable farmers to recover from that damage, preferably in forms that contribute to long-term development.

Individual or Multipest Strategies?

General agreement exists that sustainable protection of crops and livestock requires comprehensive, multipest management solutions. But, some do not agree that management strategies for locusts and grasshoppers should be integrated into multipest management schemes of single organizations, such as the national crop protection services. They note that certain insects require distinctly different control efforts by actors at different levels. Some species, e.g., the Senegalese grasshopper and African Migratory Locust, breed in areas where dryland farming predominates and can be monitored by farmer committees and integrated into multipest management by the national crop protection services and farmers. Generally this approach could apply to most grasshoppers. On the other hand, species such as the Red Locust, Brown Locust, and especially the Desert Locust, breed in remote areas and migrate across boundaries. They may be more effectively dealt with as individual species based on interstate or regional cooperation. Proposals are now being considered for a regional ad hoc task force to control the Desert Locust in "strategic" areas outside of West Africa's croplands. The same role was proposed for the regional organization DLCO-EA in Eastern Africa.

However, addressing locust and grasshopper problems within the context of broader pest problems would have several advantages: costs would drop relative to benefits because benefits would accrue each year rather than sporadically; institutional continuity and expertise would be built; already-existing organizations could respond more quicly to outbreaks and they could accommodate shifting pest problems methodically; pesticides could be turned over and replenished more rapidly so less waste would occur (95). The constraints to adopting a multipest strategy are often political and institutional rather than technical. If they can be overcome, economic savings and improved chances of sustainability maybe achieved.

When and Where Should Control Programs Be Mounted?

During the recent grasshopper and locust campaigns vast areas were sprayed with insecticides. The high costs of these efforts, including the less clearly documented environmental costs, require a reexamination of where and when spraying should be done when future outbreaks occur. Some decisions could be worked out ahead of time, e.g., the level of infestation required for control of the various species, by representatives of African and donor organizations. Alternately, various control strategies could be selected and coupled with improved plans for carefully monitoring their impact.

Many experts conclude that early treatment, especially of hopper bands, is most efficient, and the economic, institutional, and environmental costs of control increase with waiting (99). For example, carbaryl and malathion are much more economically applied against U.S. rangeland grasshoppers earl in their life cycle; optimal control occurred at tie fourth instar when grasshoppers were beginning to cause enough crop damage to justify control costs yet populations were still relatively small so control could be limited (66).

On the other hand, some propose later treatment, perhaps waiting until swarms pose an actual threat to crops and not spraying rangeland and forests at all unless they border threatened cropland. This approach increases the risk of crop damage because insects can move quickly and significant time is required to mount a spray operation. When environmental conditions are right, for example, gregarious swarms of the Desert Locust appear more or less simultaneously over a large area (4). Under these conditions insects could threaten crops before a spray operation could be mounted. Thus, a late spraying approach may have high political costs (71, 121).

Others propose careful review of the lessons learned in controlling analogous pests, such as the Australian Plague Locust or quelea birds. Quelea bird populations can increase rapidly after rains, but the control strategy is to kill only those birds actually attacking crops. Likewise, methods developed elsewhere to make pest control more effective could be applied to locust programs. For example, general information is available on the relative merits, disadvantages, costs, and uses of various ground- and aerial-spraying methods (95, 118). Some pest surveys have been organized for international chemical control efforts, but little information is available on nonchemical efforts (37). And few of the recent grasshopper and locust spray operations were followed by post-application assessments of numbers of insects killed that would help in future decision-making regarding control tactics.

The U.S. Forest Service (USFS) developed a system for monitoring gypsy moth populations to determine when and whereto mount control and for assessing control operations to determine which were most effective. This program illustrates the type of work needed to improve locust and grasshopper control. Special "forest pest management" groups lay out plots for gypsy-moth treatment and decide the appropriate time to do treatment, based on a threshold number of eggpods and stage of development of the caterpillar. Aerial treatment is done during specified weather conditions. Then, the pest management groups revisit anumberof treated plots at 7, 14, and 21 days to check the number of insects killed. Usually thesameteamdoes pre-and post-application assessments. Dataonapplication (e.g., formulation, characteristics of the equipment and plane, pilot's name) and, when possible, treatment results for each plot are recorded on standardized forms. From this data, the USFS learned that results depended significantly on which pilot did the spraying, and that treatment should begin at lower thresholds so that smaller areas could be sprayed (59). These methods and lessons may be directly applicable to grasshopper and locust programs.

Resolving issues of when and whereto control locusts and grasshoppers is USAID's responsibility. Policymakers need to listen to all sides of the debate, examine available evidence, and then determine ways to be more selective regarding timing and target sites to reduce costs (including environmental costs) and maximize effectiveness.

WHAT CONTRALTO USE: THE ROLE OF TECHNOLOGY

The choice of technology to control grasshoppers and locusts, as for other purposes, carries with it a variety of consequences. Some technologies can play a strong development role while others can hinder development. Often, support for in-

dividual types of technologies sets up complex trade-offs.

The decision to support widespread pesticide use for agriculture is such a case. In effect, donor-supplied pesticides subsidize high pesticide use. Because of these subsidies, users paid from 85 percent to only 10 percent of the real cost of pesticides in one study of nine developing countries. Users paid only 11 percent of the real cost in Senegal and 33 percent in Ghana, the two African countries included; these subsidies were worth $4 million and $20 million, respectively (80). As a result, farmers have decreased or abandoned alternative control methods–such as sound agronomic practices and varietal selection–in favor of pesticides. The social and environmental side effects of these changes are largely undocumented but may be significant. For example, increased pesticide use was among the factors that accompanied the increased commercialization of agriculture. This process has increased demands on women farmers' labor, reduced the amount of food grown for local consumption, and encouraged planting higher value crops.

Today, widespread pesticide spraying is the predominant technology used against grasshoppers and locusts. Usually, effective pest management for crops includes a larger number and wider variety of options (table 3-2). Implementing a long-term development approach to locust and grasshopper management requires broadening the current range of technologies and identifying or developing ones that can be used by various groups in environmentally, economically, and institutionally sustainable ways. Integrated pest management, joined with various forms of early warning, are two types of technology that hold promise. Both require additional research to be fully operational.

Integrated Pest Management

Finding: Integrated pest management is USAID's stated policy, but many elements of such an approach were not adequately emphasized during the recent grasshopper and locust campaigns, partly because of lack of available technology and partly because of the poor performance of donors and African agencies. If USAID intends to implement &policy fully, the Agency must support research to develop alternatives to widespread spraying, collect data on economic injury levels of crops, assess the effectiveness of various control strategies, and revise its approach based on these efforts.

Integrated pest management is "the optimization of pest control in an economically and ecologically sound manner accomplished by the coordinated use of multiple tactics to assure stable crop production and to maintain pest damage below economic injury level while minimizing hazards to humans, animals, plants, and the environment. In its broadest form an IPM program encompasses all significant components of the agroecosystem–soil, crops, water, air, insects, pathogens, weeds, nematodes, and other organisms--which interact among themselves and with other components of the system." (125).

Integrated pest management combines a variety of control techniques to reduce and keep pest populations at acceptable levels, based on criteria of crop yield, profit, and safety. It seeks maximum use of biological control, pest-resistant crop varieties, and cultural practices. Pesticides are normally used only after the target pest reaches an infestation level called economic threshold or economic injury level, i.e., a pest density at which the costs of control "just equal crop returns. Even if insecticides are the only control option available, an IPM approach stipulates that the chemicals be used as effectively and efficiently as possible and their environmental and health impacts be monitored carefully.

Furthermore, IPM can be described as a way of thinking, a process of dealing with a problem holistically. This approach requires flexibility and the ability to deal with multiple factors at one time. Practitioners must be discriminating, adapting the same principles to different situations, rather than applying a single solution to all cases in a narrow, black or white way of thinking. In this sense, mediating diplomatic solutions to border disputes could be considered part of an IPM strategy for locust control in Africa.

Promotion of IPM is USAID policy. However, it still is not used widely within USAID's agricultural and health projects. The Agency tends to support IPM in special projects rather than integrating it into overall development strategy and programs (22). Many feel that USAID should support increased research on IPM and make in-

Table 3-2–Control Tactics Now Employed Against Major Pests of Wheat in the U.S. Great Plains and Sorghum in Texas

Major pests	Biological: Pred.[a] and para.	Biological: Microbial	Host plant resistance	Cultural: Sanitation	Cultural: Eliminating hosts	Cultural: Crop rotation	Cultural: Planting date	Cultural: Clean Seed	Cultural: Water mgnt.	Cultural: Fertility mgnt.	Cultural: Tillage	Chemical: Soil	Chemical: Seed	Chemical: Foliar	Other: Monitoring	Other: Predictive models
Wheat:																
Hessian fly[b]	1	1	3	2	2	1	2	1	1	1	2	2	1	1	3	1
Greenbug[b]	1	1	1	1	2	1	1	1	1	2	1	1	1	3	2	1
Wheat stem sawfly’	1	1	2	1	2	1	1	1	1	1	2	1	1	1	2	1
Army worms[c]	1	1	1	1	1	1	1	1	1	1	1	1	1	3	2	2
Cutworms[c]	1	1	1	1	1	1	2	1	1	1	2	1	1	3	2	2
Aphids[c]	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1
Grasshoppers[c]	1	1	1	1	1	1	2	1	1	1	1	2	1	3	2	1
Wheat stem maggot[c]	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1
False wireworm[c]	1	1	1	1	1	2	1	1	1	1	2	2	1	1	2	1
True wireworm[c]	1	1	1	1	1	2	1	1	1	1	2	2	1	1	2	1
Sorghum:																
White grub	1	1	1	2	2	2	2	1	1	1	1	3	1	1	1	1
Wireworms	1	1	1	2	2	3	2	1	1	1	1	2	3	1	1	1
Greenbug aphid[b]	2	1	3	1	1	1	2	1	1	1	1	1	1	3	2	1
Fall army worm[b]	1	1	1	1	1	1	3	1	1	1	1	1	1	2	1	1
Beet army worm[b]	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1
S.W. corn borer[b]	1	1	1	3	1	2	2	1	1	1	1	1	1	1	1	1
Sugarcane borer	1	1	1	3	1	2	3	1	1	1	1	1	1	1	1	1
Chinch bug	1	“ 1	2	1	2	1	2	1	1	1	1	1	1	2	1	1
Sorghum midge[b]	1	1	1	1	1	1	3	1	1	1	1	1	1	3	1	1
Sorghum webworm	1															

NOTES:
[a]Predators and parasites
[b]introduced pest
‘native pest

KEY: 1 = little or no use
2 = some use
3 = major use

SOURCE: U.S. Congress, Office of Technology Assessment, ***Pest Management Strategies in Crop Protection, vol.*** 1- Summary (Springfield, VA: National Technical Information Service, October 1979, pp.22, 54).

creased efforts to integrate 1PM in the majority of its agricultural programs. Generally, the concept of IPM is not well-understood by decisionmakers. For example, most USAID officials responsible for the grasshopper and locust program maintain that 1PM does not apply to grasshopper and locust control during upsurges (44).

However, various elements of 1PM nevertheless were clearly appropriate during the recent campaigns and poorly implemented:

Optimization of control–This refers to efficient and effective use of resources, differing from maximization of control. The large numbers of hectares sprayed could have been treated far more effectively with available technologies. Pinpointing targets, improved consideration of wind drift, ground temperature, time of day, stage of insect development–among other things–would have greatly unproved efficiency.

Multiple control tactics-These were not used because control methods against migrating swarms are limited. The lack of alternative methods, however, reflects the lack of resources and low priority given to developing them. Donors could have set aside more resources for developing alternatives rather than spending the overwhelming proportion of their funds on emergency spraying.

Pest damage kept below the economic injury level (EIL) to maintain stable crop production-Major crop loss due to grasshoppers and locusts did not seem to occur at the national level in 1986 to 1989, although some individual farms suffered significant losses (18). By and large, swarms did not affect croplands. In some cases, spraying seemed to protect crops. The lack of damage cannot be attributed automatically to control, however, because of the complex relationship among increased rainfall, insect upsurges, and crop yield. High rainfall in the mid-1980s increased crop growth in many areas, making "stable crop production" difficult to calculate. Reliable data needed to sort out these various factors are lacking so it is also difficult to determine economic injury level accurately. Even so, little, if any, effort was made to base decisions to spray particular areas on such a determination.

Minimal hazards to people and the environment–At best, this element of IPM was not carried out consistently, despite efforts by USAID and others. For example, broad-spectrum insecticides killed nontarget organisms, and disposal of excess pesticides and their containers remains problematic.

Relatively workable 1PM programs have been developed for a range of pests and crops and are being used in some developing areas (103). The cost-benefit analyses of those programs evaluated generally show a reduction in pesticide use and an increase in profits (35). 1PM has not been emphasized in locust and grasshopper control in Africa and the Middle East, however (95). Today, biological control, cultural practices, and other nonchemical components of 1PM cannot provide the high level of control needed to stop gregarious hopper bands and swarms of adults. These methods might, however, contribute significantly when used together or at early stages of an infestation (9).

An effective 1PM program would aim to prevent serious locust and grasshopper outbreaks. It could include activities at a variety of levels, but regional aspects would be necessary due to the cross-boundary migration of insects. New 1PM approaches would rely on controlling locusts and grasshoppers at earlier points than achieved in the recent campaign, similar to the "strategic control" advocated by FAO for the Desert Locust, but place a greater emphasis on using alternatives to spraying as these become known or available.

Examples of 1PM strategies for grasshoppers and locusts might include planting alternative crops that are less susceptible to these insects; increasing animal production; developing cottage industries to preduce locust meal for food or to produce extracts from neem trees for use as an antifeedant (126), and developing pesticide regulations to improve chemical use. Sound land management-especially reforestation, upgrading range quality, and avoidance of overgrazing and widespread burning-can suppress grasshoppers and locusts and decrease suitable breeding sites (95). This and other approaches might be part of an IPM approach for some other species as well.

Certain aspects of an IPM approach to grasshopper and locust problems could be implemented immediately, e.g., improved use of pesticides. In the short-term, improved regulation, selection, storage, application, and disposal of pesticides maybe the best strategy, especially for reasserting control after an upsurge (95). Mechanical and cultural methods of control are also currently available and these might be suitable for controlling small infestations in crops. They are most likely to be useful for the Variegated Grasshopper, especially if paired with additional training for extension agents.

Research on microbial and botanical pesticides, insect population modeling, forecasting, developing resistant crop varieties, and further improvements in insecticide application offer a better outlook in the medium and long-term (95). Distinct approaches will have to be developed for each of the major locust and grasshopper species, however. For example, since the Desert Locust eats many types of vegetation, developing resistant plant varieties does not seem to be a feasible approach to controlling it.

Biological Control

Normally, naturally occurring biological control is not sufficient to prevent outbreaks of major locust and grasshopper species (93). But enhanced biological control-the use or encouragement of natural enemies for the reduction of pests-is one potential component of an improved IPM approach. Locusts and grasshoppers have an array of natural enemies. So far, these have not been used in control campaigns, nor has what is known about natural pest mortality been exploited to produce predictable or consistent results (95). Some feel that biological control offers considerable potential, although additional research and field testing are required before their real value will be known. Because of the priority currently given to chemical control, much of the research on alternative methods is in its early stages.

Some biological control agents, when packaged, are called microbial pesticides. Most have the advantage of easy deployment; they could be formulated and sprayed or used as baits in much the same way that chemical insecticides are now. Some newer biotechnology may be helpful in developing these alternatives. However, microbial controls require EPA registration for commercialization and such approval is difficult to obtain for genetically engineered microorganisms. Similarly, African governments want reassurance that these biological control agents do not pose hazards to human or animal health.

Grasshoppers and locusts are susceptible to infection by bacteria, viruses, fungi, and protozoa and several potential new microbial control methods are being tested. *Nosema locustae*, the first protozoa registered by EPA for use against an insect, is approved for control of U.S. rangeland grasshoppers. Developed at USDA's Agricultural Research Service's Range Insect Control Research Unit in Bozeman, Montana, it is sold commercially as Nolobait. Used with a wheat-bran bait, it takes 3 to 4 weeks to kill 50 to 60 percent of the insects and persists for two seasons because it is passed from one generation to another. It is less expensive than chemical insecticides and does not adversely affect beneficial species or other natural enemies (21, 88). Field experiments in Cape Verde and Mauritania showed that native grasshoppers were infected with *Nosema* (39) but did not determine whether it could suppress grasshopper outbreaks (9). USAID supported *Nosema* research in Mali; it was stopped in 1988 due to Malian Government fears of possible hazards (99). USAID supports further work on *Nosema* and other microorganisms in Cape Verde by USDA scientists and the national agricultural research service. Several recent studies suggest that further research in Africa on various species of *Nosema* may pay off for grasshopper and locust control (95, 99). USDA and other researchers began examining viruses as potential control agents because viruses are more deadly, kill faster, and could be used in combination with slower-acting microbial. For example, an entomopoxvirus for the Senegalese grasshopper shows potential as a microbial control agent (94). The fungal pathogen Entomophaga grylli attacks some locusts and grasshoppers. It has not been studied in Africa or the Middle East (95), but its potential in semi-arid areas where most grasshoppers occur seems small because fungal development depends on high humidity (94). It may be useful in Africa's humid areas, however, for these same reasons. Some new strains of spore- or toxin-forming bacteria (like those used already for biological control for other insects) might be isolated from locusts and grasshoppers (78). Rickettsia are virulent to grasshoppers, but their use may be too hazardous to have much potential because they also infect vertebrates (94).

Other Biorational Controls Materials

These include botanical pesticides and pheromone traps-alternatives to Synthetic chemical insecticides. One botanical insecticide has received attention, especially for its antifeedant effects. Extracts from neem trees (Azadirachta indica) discourage locusts, grasshoppers, and other insects from feeding on plants to which it is applied (9). In India, neem spray and dust protected crops from Desert Locusts and, in Togo, neem repelled grasshoppers. However, 1988 trials at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Niger were less than successful and indicated that farmers might be unwilling to invest the labor or funds to use neem on grain crops, since repeat applications are needed (99). A neem insecticide, Margosan-0, is being distributed in the United States by W.R. Grace and Co., but EPA has not approved its use for food crops. The authors of USAID's Programmatic Environmental Review and the AELGA evaluation supported further research on neem as an antifeedant.

The Egyptian Government supports research on the antifeedant properties of a number of indigenous plants, and the German Agency for Technical Cooperation (GTZ) funds trials with neem, *Nosema,* and other natural agents as part of its program of developing alternative methods of locust and grasshopper control (107).

The International Center on Insect Physiology and Ecology (ICIPE) and others are attempting to identify natural attractants. Recently, ICIPE achieved some success using pheromones (natural attractants) as bait to trap certain species of the tsetse fly (Washington Post, April 3, 1989). Like biological control agents, attractants are usually narrow-spectrum and thus less harmful to nontarget organisms and the environment than broad-spectrum chemical insecticides. The potential for using pheromones for grasshopper or locust control is not known and many fear that pheromone work is not justified for this reason (6).

New Research on Alternative Controls

Those engaged in planning and conducting research on biological control agents, especially the microbial ones, stress that it maybe 8 to 10 years or longer before these will be ready for large-scale use (55, 65). First, the microorganisms have to be identified and isolated from locusts and grasshoppers in Africa (40). Then various formulations must be field tested against target species and nontarget organisms under various conditions and these results corroborated. Finally, ways to mass-produce and apply the agents must be developed and tested. Research projects such as these require long-term institutional support for an agency to attract qualified scientists and sustain their work.

The International Institute for Tropical Agriculture (IITA) recently began a major research effort on biological control of grasshopper and locusts. The $1.0 million USAID-funded project aims to develop strains of two fungal pathogens recovered from locusts and grasshoppers in Africa as biological pesticides and field test them in the Sahel. Work Will be led by scientists from the London-based Commonwealth Agricultural Bureau International's Institute for Biological Control at IITA's facility in Benin.

ICIPE also proposes a major research initiative. By late 1989, ICIPE had received $0.5 million from the World Bank and African Development Bank toward the $14 million requested for the first 5-year phase, 1989 to 1993. ICIPE's proposal encompasses five areas of research on alternative control methods, including biorational agents and improved chemical insecticides:

- **population dynamics (to detect potentially dangerous populations during recessions);**
- **pheromones and kairomones (to use as attractants in locust control);**
- **endocrinology of locust phase-changes and gregarious behavior (to pinpoint targets for growth regulators and broad-spectrum chemical insecticides);**
- **biological control (to augment role of pathogens and parasites, including enhancing their virulence by genetic manipulation); and**
- **new approaches to the use of baits (since they tend not to affect natural enemies and nontarget organisms).**

Monitoring Insects, Weather, and Vegetation

Finding: Technologies for ground monitoring insect populations are adequate but sometimes are used ineffectively. Technologies for monitoring from the air tend to be imprecise and their results often delivered late. Therefore, technological and institutional improvements are needed for ground and aerial surveillance and forecasting, necessary components of a preventive strategy.

Monitoring is essential for a number of purposes. A preventive approach to locust and grasshopper control requires forecasting, ground monitoring, and early treatment to interrupt swarm formation. Effective pest management strategies require monitoring, or tracking, insect populations before control to find, identify, and delimit infestations and further monitoring after control to assess its effectiveness. Famine early warning systems benefit from information on fluctuating insect populations.

Technologies

Methods already exist for monitoring pest populations on the ground and for measuring the impacts of control but their use needs to be improved, especially by increasing national capacity.

Today, most remote sensing and forecasting work is done by expatriates at scientific centers in Europe, the United States, or regional centers without adeqate, timely, and accurate field data. Consequently, African field programs remain largely untouched by the technological advances at remote sensing centers; quickly exchangig information between the field and centers is difficult (95); and often forecasts are wrong.

An array of detection strategies, each appropriate for specific times and locations, can improve forecasting. Some information can be obtained only by ground survey teams (insect species, stage of development, population density). Other information can be obtained best from aircraft and satellites (current and likely future vegetation, wind and rainfall patterns). Combining remote sensing data with maps showing: 1) political boundaries, roads, and landmarks, 2) historic breeding areas and migration patterns, and 3) insects' soil and vegetation preferences can be used to help ground survey teams select high priority areas for monitoring. (George Popov prepared maps on the preferred habitats of the Desert Locust in the Sahel for FAO but these are not yet available to national crop protection services.)

All aerial survey methods require ground verification. Thus, they cannot substitute for crucial ground monitoring and improved integration of the two methods is critical. For example, information from remote sensing could better guide the work of ground teams just as insect population data from ground teams could supplement the vegetative cover data provided by remote sensing.

The most critical component of early detection of pest populations is a network of trained ground observers (37) with adequate equipment. Thus, training remains one of the most important needs for improved field applications of forecasting. Training could encourage managers to make greater use of remote sensing and provide a cadre of field officers for various early warning and survey activities, including data interpretation (95). Certain aspects of monitoring programs are unresolved. For example, some feel that a monitoring system designed for pest complexes would be a more efficient use of resources than ones designed for single insect pests. Any effective system, however, must include many levels of organizations, working within the framework of national and regional programs, to improve accuracy and sustainability.

Types of Early Warning and Forecasting Systems

Current early warning systems combine remote sensing data with other aerial, ground, and statistical information for a variety of purposes, such as agricultural and environmental assessment and resource management (45). AGRHYMET data, for example, are used for crop and pasture monitoring in the Sahel.

Several groups monitor pest damage as one of several major risks to agricultural production to predict food shortages and famine, and thus anticipate the need for food aid and other forms of assistance. USAID's Famine Early Warning System (FEWS) and FAO'S Global Information and Early Warning System are examples.

Three major organizations make or plan to make locust and grasshopper forecasts specifically: 1) FAO/ECLO through the ARTEMI (Africa Real-Time Environmental Modeling Using Imaging Satellites) project, 2) the French research agency, PRIFAS (Programme de Recherches Interdisciplinary Francais sur les Acridiens au Sahel, reorganized now as Acridologie Operationnelle-Ecoforce Internationale), and 3) the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) meteorology agency, AGRHYMET (99). These type of programs have significant potential. For example, a model predicting upsurges and locations of the African Migratory Locust, developed by a pint FAO/U.N. Development Programme project, reduced annual scouting efforts from 144 to 90 person-months (2).

Current programs also have serious limitations. Reports from PRIFAS and ELCO often are not quantified, detailed, or timely enough to be useful in the field. For example, Operation SAS (Surveillance des Acridiens au Sahel) was established within the French PRIFAS for rapid collection of field observations from a Sahel-wide network. However, data collection has been slow, sporadic, and incomplete, preventing reliable prediction (99). Also, the biweekly SAS newsletter has been istributed too slowly for recipients to use it for planning; it is used primarily as a situation summary. SAS first constructed a predictive model for the Senegalese Grasshopper and used historical records, G. Popov's qualitative vegetation and soil maps, and AGRHYMET weather data (often relying on 30-year averages) but not remote sensing data. In the past 5 years, PRIFAS has been developing a similar model for the Desert Locust and is working with AGRHYMET to set u a locust survey and warning service for the CILS countries (75).

The ECLO in FAO/Rome provides faster information because its monthly "Desert Locust Summary" is sent by fax. FAO combines data from field reports and remote sensing. Originally, FAO used Landsat data, but now uses Meteosat and National Oceanic and Atmospheric Administration (NOAA) imagery in the Dutch-designed ARTEMIS system. FAO also uses this technology to produce 10- and 30-day rainfall maps, relying on the European Centre for Medium-Range Weather Forecasting for forecasts of temperature, pressure, wind, and rain for up to 5 days in advance (13). Like the SAS Bulletin, however, FAO'S "Desert Locust Summary" is plagued by gaps in coverage due to missing field data (95).

FAO'S separate "Update" includes a general status report, a 1-month forecast, descriptions of weather and ecological conditions, specific country information on pests sighted and assistance requested, and assistance provided bydonors. Recently, ECLO entered historical data on locust plagues in its computerized database and plans to use it in forecasting locust migration patterns.

Remote Sensing and Greenness Maps

Satellite-based weather, vegetation and land surveys, maps, etc., are all likely to be useful for building scientific institutional capacity in African countries. Such information can be used for government @arming and regulation and for monitoring desertification, vegetation, surface features, wind patterns, etc. Probably satellite-based remote sensing will be used less for locust and grasshopper forecasting and control than for these purposes. In 1988, the multidonor Club du Sahel commissioned a study of 50 remote sensing projects in the Sahel. Remote sensing seemed very useful for climatological applications, less useful for crop monitoring (although vegetation indexes were of some use), and least useful for forecasting yields because of difficulties in measuring crop acreage and discriminating between crops (67).

USAID sponsored the development of greenness maps, one particular type of vegetation index, by the U.S. Geological Survey (USGS) in 1987. Greenness maps were furnished to five Sahelian countries every 2 weeks between 1987 and 1989 by the USGS EROS (Earth Resources Observation Systems) data center in South Dakota, using data from NOAA satellites. These maps showed changes in vegetation over time. FAO's ARTEMIS program also monitors rainfall and changes in vegetative cover. These maps helped field teams identify places where locusts might be found and areas where ground surveillance was not needed (95), especially in places where rainfall is irregular and ground cover inconsistent.

The USGS greenness maps were valued highly by those interviewed during the AELGA evaluation but were judged not too useful for making control decisions because delivery to Africa took up to 2 weeks (in 1987) or 8 days (in 1988). As a result, maps were sent by fax to Mauritania and

Niger by late 1989 (121). Both USGS and the ARTEMIS maps have another weakness that is less easily corrected. Areas with very low amounts of vegetative cover may not show up on existing satellite imagery yet be areas where potentially damaging Desert Locust populations develop (13).

Imagery for grasshopper and locust control is or can be provided by several types of satellites:

- Meteosat, operated by the European Space Agency;
- weather satellites operated by NOAA (part of the U.S. Commerce Department);
- Landsat, developed by the National Aeronautics and Space Administration but owned since 1984 by the private U.S. Earth Observation Satellite Co.; and
- the French Systeme Probatoire d'Observation de la Terre (SPOT) (figure 3-1).

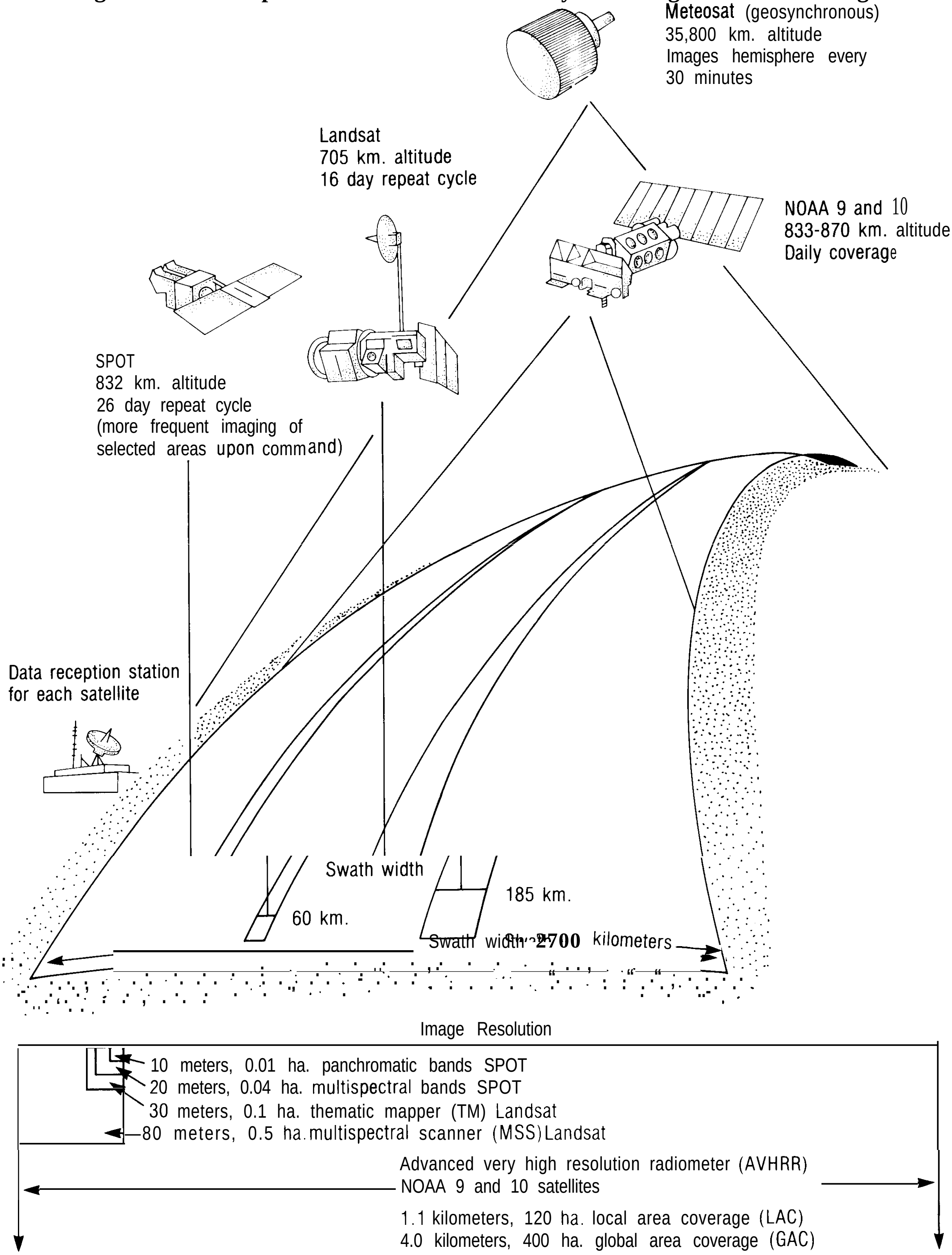
The first two are used by those monitoring insects now; the second two provide more detailed information on land cover. Landsat has greater resolution than NOAA's polar orbiting satellites but NOAA provides daily coverage while Landsat passes over the same areas only once every 16 days. Landsat has not proven capable of monitoring crop production (26) and obtaining Landsat data is more expensive than from NOAA satellites so FEWS and USGS rely on NOAA's system. In general, a confusing array of Earth-monitoring satellites exist, and the U.S. Government has been criticized by scientists and others for having spent too much on satellite hardware that produces too much inaccessible and unanalyzed data (56).

USAID plans to transfer significant aspects of U.S. remote sensing application to locust forecasting to African countries or regional organizations (62). USGS, which has supported AGRHYMET for a number of years, recently trained AGRHYMET staff and key personnel of the Sahelian national crop protection services to use greenness maps. Also, USGS technicians are training AGRHYMET staff to produce and distribute their own greenness maps (99). AGRYHMET is expected to provide this service to its nine member states in 1990, according to some sources (45,62), or within the next 3 years, according to others (99). Similarly, USGS is transferring greenness map-making capability to Tunisia for Northwest African and planning to develop it in Djibouti for the six East African nations (62). USAID is funding installation of a satellite dish in Niger so AGRHYMET will be able to receive data directly from the NOAA weather satellites.

Currently, remote sensing for early warning of grasshopper and locust upsurges is not considered fully operational nor does rapid transmission from satellite to Earth ensure that all stages of data gathering, analysis, and use are coordinated and rapid (95). One perceived danger is that, as these programs develop, remote sensing will dominate other types of information-gathering, thereby reducing the resources available for field scouting. For example, observers are concerned that FAO's interest in a very expensive, centralized program based in Rome may preclude other, less glamorous, approaches. On the more promising side, plans exist to extend satellite-based monitoring to other important migratory pests such as the grain-eating quelea bird, the African Migratory Locust, the Senegalese Grasshopper, armyworms, and the Red Locust (95).

The various groups conducting early warning and remote sensing activities do not necessarily duplicate efforts because they operate with different mandates for research, applications, information dissemination, and training. Nevertheless, clear duplication of effort exists and improved coordination and cooperation is needed (95). International organizations are most suited to provide support for remote sensing, due to the high cost of equipment and the complexity of support services, but regional groups might be responsible for establishing uniform reporting systems.

Figure 3-1-Principal Satellites Used in Early Warning and Forecasting



SOURCE: TAMS Consultants, Inc. and Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment*, Main Report, contractor report prepared for the Agency for International Development, March 1989, p. D-7.

Chapter 4

Policy Options for Congress and the Executive Branch

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Chapter 4

Policy Options for Congress and the Executive Branch

WHERE WE STAND TODAY

Oversight, Not Micromanagement, Is the Goal

OTA's work suggests that no major new U.S. authorizing legislation is needed to improve locust and grasshopper control at this time. Supportive elements could be added to the Foreign Assistance Act or the Farm Bill, however. These laws set out key dimensions of U.S. foreign aid and agricultural policy. Thus, this legislation could appropriately include statements regarding U.S. adherence to economically, institutionally, and environmentally sustainable pest management as one element of successful agricultural and international development.

A great deal of uncertainty exists regarding the nature of grasshopper and locust problems, the costs, benefits, and impacts of control, and the desirability of various future approaches. OTA cannot confidently suggest specific areas in which funding might be adjusted with numerical benchmarks given this high degree of uncertainty. The international control efforts of 1986 and 1989 did little to resolve important questions. Instead, the U.S. Agency for International Development (USAID) seems unable to:

- **find long-term solutions to problems such as grasshopper and locust upsurges that have episodic and chronic dimensions;**
- **take advantage of recession periods to put into place preventive programs; or**
- **research alternative controls effectively.**

In these circumstances, congressional action might best be directed toward helping U.S. officials decrease the uncertainty surrounding locust and grasshopper programs by requesting that USAID carefully review what is known and not known, assign priorities for gathering information, and improve strategies to deal with future pest problems. Congress' oversight role is key and this can be done by the relevant authorizing and appropriations committees. Boxes A through D set out possible oversight questions and options to help Congress play that role.

Congress' micromanagement of USAID is not the goal. USAID's failure to answer these strategic questions, however, has left a policy vacuum. If USAID is unable to fill the vacuum, Congress has little choice but to become more involved if U.S. programs are to be effective.

Danger exists that the United States will respond to the next pest upsurges in the same costly way as before, with strategies based on questionable premises. Public support of disaster assistance increases this probability. Danger also exists **that special interest groups will exert undue policy influence and that decisions will be ill-informed.** For example, tied aid requirements for the use of American-made commodities mean that U.S. pesticide manufacturers have a vested interest in maintaining a control strategy based almost exclusively on insecticide use. They can be expected to over-stress benefits, overlook difficulties of following safer practices in Africa, and minimize the hazards of insecticide use. On the other hand, environmental groups have legal power to sue USAID if environmental laws and regulations are not met. They can be expected to emphasize the hazards of insecticide use, to over-stress the potential of alternative controls, and to favor natural resource protection over economic development.

USAID responds to all of these pressures. At the same time, USAID has the political and economic power to influence, if not determine, the shape of grasshopper and locust management worldwide. U.S. financial contributions to control are sizable and USAID has placed effective conditions on the use of these funds. The United States is perceived by many to have the technical resources for pest management generally.

On the whole, USAID has assumed a reactive, rather than a proactive, posture toward Congress as well as other pressure groups. So far, USAID's grasshopper and locust work has escaped the kind of scrutiny that it deserves. Generally, Congress' reporting requirements have been counterproductive, deflecting attention from more fundamental issues and glaring missteps:

> Nena Vreeland of CDIE [USAID's Center for Development Information and Evaluation] found out from interviews that [USAID] field professionals spend about 6 percent of their time on reporting requirements to Congress and another 20 percent on reorting to [USAID]/Washington. As one [USAID] staff member pointed out, 'Development is something that [USAID] does on a Thursday afternoon." (98)

Thus, OTA does not intend that the improved oversight discussed here be done on a haphazard basis by Congress nor be used by USAID to generate stacks of irrelevant and unread paper. Instead, Congress and USAID need to engage in a thoughtful dialogue with effective follow-through. Perhaps it is time to involve additional outsiders in this process and to mediate the process deliberately. In this chapter, OTA highlights recommendations from several other recent studies related to pest management in development, then turns to policy changes within USAID and options for Congress.

Recommendations From Other Studies

OTA's study complements three recent reports (22, 95, 99). The options considered here are generally consistent with recommendations in one or more of the reports (app. F). Each report fulfilled congressional requirements; each was contracted externally but conducted with the assistance of USAID staff.

USAID contracted *Opportunities to Assist Developing Countries in the Proper Use of Agricultural and Industrial Chemicals (22)* to comply with a 1987 Foreign Assistance Act amendment by Rep. David Obey's Appropriations Subcommittee on Foreign Operations, Export Financing, and Trade. It was prepared by the Committee on Health and the Environment (which included representatives of environmental groups, industry, labor organizations, and universities) with help from the Conservation Foundation. Its scope included chemical use for industry as well as agriculture and industry; that distinguished it from the following two reports.

A Programmatic Environmental Assessment for African and Asian locust and grasshopper control programs (95) was prepared by TAMS Consultants and the Consortium for International Crop Protection. This fulfilled USAID's statutory requirement to assess the environmental impact of overseas operations and the Agency's internal environmental regulations. On the whole, this is considered a comprehensive and balanced presentation, and OTA's analysis relies heavily on it. Also, this report has had a significant impact on USAID: a task force has met regularly since mid-1989 to consider ways of implementing the report's recommendations.

The third study, a mid-term evaluation of USAID's Africa Emergency Locust/Grasshopper Assistance (AELGA) project, was conducted by Tropical Research and Development (99). This, unlike the others, was not a completely independent external review because an USAID entomologist served on the three-person analytical team. It assesses the progress of a number of USAID projects through mid-1989 with the emphasis on locust and grasshopper control programs in five Sahelian countries.

The recommendations from these three studies have some similarities and differences:

- Integrated Pest Management (IPM): The Conservation Foundation report and the Programmatic Environmental Assessment emphasize that USAID should increase use of IPM, with the goal of making IPM its primary pest management approach as well as its stated policy. But the AELGA evaluation omits IPM from its major recommendations, confining the IPM discussion to an annex on research.
- Improved Use of Pesticides: All three reports recommend improved use of pesticides as consistent with an IPM approach, and they also stress the need for monitoring health and environmental effects of insecticide use and improved environmental protection. For example, the Programmatic Environmental Assessment recommends prohibiting insecticide

application in environmentally sensitive areas (such as near bodies of water or in areas containing endangered species), minimizing the area sprayed, and using economic thresholds for deciding if and when to spray.

- Cumulative Impacts of Control: The Programmatic Environmental Assessment and the AELGA evaluation address the problem of cumulative impacts of pesticides used in health and agricultural programs.
- Training: all emphasize providing training and technical assistance to various groups, such as crop protection personnel, USAID staff, and African farmers, on various topics, e.g., safe and sound pesticide use, storage, and disposal.
- Control Alternatives: All endorse increased research on alternative technologies. The Programmatic Environmental Assessment and the AELGA evaluation advocate field-based economic research as well. The Conservation Foundation stresses linking research with the perspectives of project beneficiaries. The Programmatic Environmental Assessment recommends field testing *Nosema* and other biological agents such as neem extracts.
- The Role of Different Groups: The AELGA evaluation and Conservation Foundation report give more attention to institutional factors and USAID management than the Programmatic Environmental Assessment, although all advise involving international, regional, national, and local organizations and coordinating efforts.

In addition to these reports, USAID has its own reservoir of newly acquired data. Some preliminary work has been done by USAID's Office of Foreign Disaster Assistance (OFDA) internally to tap lessons learned, mission cable traffic contains similar lesson. The minutes of USAID meetings in Harper's Ferry, WV, and Dakar, Senegal provide some insights from the field. Also, USAID mission staff have access to information from African government agencies that could be compiled and analyzed. OTA finds that the three reports described here, along with these other sources of information, can form the basis for initiatives in several important areas.

POLICY OPTIONS

Revising USAID's Strategy

Finding: USAID's strategy would require significant changes if the United States wants to play a leadership role in developing sustainable pest management strategies for Africa: giving higher priority to IPM; building inhouse scientific capacity to improve its ability to use pesticides judiciously; improving internal, interagency, and international coordination as well as improving support for various other organizations involved in pest management.

The changes needed to improve USAID's approach to pest management are substantial enough to require a shift in the way the agency views the goals of pest management and the ways in which those goals are implemented (box 4-A). For example, USAID saw its strength in conducting aerial spraying in the recent emergency effort (44). The United States contribution might instead focus more substantially on using American scientific expertise and other resources to develop alternative control methods (including safer insecticides and improved cost/benefit methods), to improve forecasts, and to improve environmental monitoring of insecticide use. Generally, the U.S. strategy should lay out a long-term, multipest approach (where possible) to pest management, one that would support preparedness and prevention while minimizing pesticide use and increasing environmental and health safeguards. Also, this plan should carefully define complementary uses of disaster and development assistance. Congress could provide USAID with overall direction, set time limits during which this strategy should be developed, implemented, and then evaluated, and provide adequate funding for the initiative.

USAID currently has enough information to revise the Africa Bureau's 1987 *Locust/Grasshopper Strategy Paper (113).* Revisions should reflect the full geographic and institutional scope of the problem as well as its episodic and chrome dimensions. For example, relevant regional bureaus, the Bureau for Science and Technology, and OFDA should participate in setting priorities for U.S. programs during upsurges and recessions. Later,

Box 4-A–Potential Congressional Oversight Questions and Congressional Policy Options: Revising USAID's Strategy

Accountability for the Past:

- How did USAID select widespread pesticide spraying for its campaigns against locusts and grasshoppers? What field-based, economic evidence justified this involvement?
- What amounts and percentages of total USAID funding to Northwest and sub-Saharan Africa from 1984 through 1990 were for pest management-of all pests, compared with that for grasshoppers and locusts? How does this compare to estimates of crop losses from different groups of pests?

Preparing for the Future:

- How are USAID's plans being revised based on recent locust/grasshopper campaigns in Africa? What will be done differently the next time?
- What alternatives to spraying might effectively increase African food security during locust and grasshopper upsurges, e.g., cutting other agricultural losses, providing food aid or supplies for replanting? How does spraying compare to these other tactics in terms of: 1) effects on farmers and 2) costs and benefits at the national level?
- What are the benefits and costs of implementing a preventive approach during locust and grasshopper recessions? How do these compare to widespread spraying?
- What management changes would help to integrate pest prevention, research, and control within USAID and other Executive Branch agencies?
- What progress has been made to implement the high priority recommendations of USAID's Programmatic Environmental Assessment? What measurable indicators, milestones, time-frames, and estimated costs have been developed for these?

Congressional Options:

Option 1: *Congress could direct USAID to revise its Locust/Grasshopper Strategy Paper for Africa that would: apply IPM during recessions and upsurges; integrate research, development, and prevention with disaster assistance; address the context in which migratory pests occur; and assign priorities among activities during recessions and upsurges.*

Option 2: *Congress could review USAID's pest management planning to ensure that earlier problems are not repeated. Congress could request short (1 page) progress reports with quantitative data and anticipated modifications, such as a breakdown of AELGA's specific activities and costs for fiscal years 1990 and 1991.*

Option 3: *Congress could invite USAID to discuss differences between its actual priorities and those recommended by its Programmatic Environmental Assessment. USAID could be asked to list objectives, milestones, timeframes, and funding of activities to implement the assessment's recommendations.*

Option 4: *Congress could ask USAID's Center for Development Information and Evaluation to do a program assessment of USAID's disaster work.*

SOURCE: Office of Technology Assessment, 1990.

USAID should revise the 1989 *Locust/Grasshopper Management Operations Guidebook* to conform with its updated strategy. The revised locust and grasshopper strategy paper might be incorporated in, or later appended to, a USAID policy document on pest management.

A number of the Programmatic Environmental Assessment's recommendations directly relate to strategic considerations and policy changes. Many of these should be incorporated into the revised USAID Strategy Paper and the updated Operations Guidebook because this is the most comprehensive analysis available on many of these issues. USAID seems to be moving to implement many of these recommendations. However, certain differences are apparent between the two sets of priorities. For example, USAID is giving higher priority to pesticide disposal and less to surveys of environmentally critical habitats.

The AELGA Project

The major USAID funding of locust and grasshopper programs currently is through the 3-year AELGA project slated to end September 30, 1990. While the AELGA project's goals encompassed emergency and long-term development, the individual components had not been carefully thought through and many specific activities suffered from poor planning. Project assumptions were not identified; constraints were not dealt with in advance; measurable objectives and realistic milestones to measure progress were not set; feasible management systems were not put in place before funding began, etc. As a result, often emergency and long-term elements did not reinforce each other in practice. Even more important, the list of things that were not done during the recent control campaigns–for example, not measuring insect kill-rates nor monitoring health and environmental impacts of spray programs–reflects the absence of budgeting time, personnel, and resources for these activities during the project planning and contracting processes. These problems should be avoided in the next phase.

A Role for Task Forces

OFDA forms task forces in response to specific disasters with the goal of improving interagency coordination. When a given disaster is perceived to have run its course, OFDA disbands its task force and other groups within USAID are expected to carry on. OTA found that the OFDA Desert Locust Task Force, with its weekly meetings and annual evaluation and planning conferences, was generally effective in coordinating the U.S. emergency response. For the locust problem, however, the task force's position in OFDA and its narrow mandate to coordinate the emergency response had serious negative consequences. OFDA disbanded the Desert Locust Task Force in June, 1989, and the people who built up knowledge during this effort moved on to new responsibilities within USAID and other U.S. agencies. The data collected during the task force's life was put into storage.

A similarly organized USAID task force with a broader mandate to examine long-term pest management might initially formulate an improved USAID strategy and plan and oversee its implementation. The broader mandate would imply a wider membership on the Pest Management Task Force and greater responsibilities for evaluation. For example, persons with solid technical expertise and those representing research, in addition to control, should be included. So should representatives of private voluntary organizations working with local farmer groups. Data gathered during the course of an upsurge should be mined rather than stored. The Pest Management Task Force might also oversee implementation of recommendations from the Programmatic Environmental Assessment and coordinate the U.S. response to various worldwide plant protection initiatives.

Initially, this Pest Management Task Force could commission an independent, external group to examine the 1986 to 1989 locust and grasshopper control programs in Africa to determine whether and/or how much these efforts contributed to stopping the plague and where costs might be cut. Attention should be given to identifying clearly where and when chemical control programs are mounted most effectively and how they could be minimized. Also, the group could provide recommendations for future U.S. programs. While this group should collaborate with U.S. agencies, it should be organized by an outside group, such as the National Research

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Council, with official responsibility in the hands of those outside the U.S. Government's locust and grasshopper control operations.

At the same time, USAID could conduct its own evaluations of disaster assistance and pest management. For example, USAID's Center for Development Information and Evaluation (CDIE), which conducts evaluations of programs both inside and outside of USAID, might examine USAID's disaster work, especially that of OFDA. In the process, CDIE might identify broad lessons learned about natural disasters, hazard mitigation, the role of disaster planning, etc., as they relate to insect outbreaks. In this context, the Federal Emergency Management Administration's experience with domestic natural hazard research and planning may be relevant.

Implementing Integrated Pest Management

Finding: Mom fully using 1PM will require a substantial investment in research, training of Africans, and improved technical capacity among USAID staff. Since IPM is a multipronged systems approach, it wilt require renewed efforts at coordination anddrawingtogether information from a variety of sources: U.S. universities, government agencies, and other donors.

The United States has important capabilities to contribute to improved pest management via 1PM. Certain U.S. organizations and individuals have substantial experience in using this systems approach. Likewise, USAID has staff who are knowledgeable about institution-building and regulation of pesticides and the U.S. scientific community has resources far beyond most developing countries. However, policy changes are needed if these capabilities are to be exploited for improved 1PM (box 4-B).

The term "integrated pest management," derived from the earlier term "integrated Pest control," was introduced by the U.S. Council on Environmental Quality in 1972. The Council promoted 1PM as an environmentally sound alternative to the misuse of pesticides m large-scale temperate agriculture. Use of the term soon spread to those working with small-scale agriculture in the tropics (8).

Developing countries usually modelled their pest management programs after those of colonial powers. So, national crop protection services, like their donor counterparts, are oriented primarily towards chemical control of pests. This orientation, however, is questionable when most of the national crop protection services' clients lack the resources to adopt this control and some of their existing agricultural practices might be better adapted to 1PM.

It seems that USAID policy regarding 1PM was not well understood nor fully implemented by those who led the recent emergency grasshopper and locust campaigns. USAID stopped funding several regional longer term 1PM efforts in Africa. Termination of funding seems justified for these specific prejects but no alternatives were developed and funded. The agency has supported imaginative and effective pest control approaches, such as an 1PM program in Honduras, however. A new USAID policy statement on 1PM, the Pest Management Sector Review, was planned (2?) for Spring 1990 but has been delayed until at least 1991. This could clarify the Agency's position, but a corresponding reallocation of resources is required. To date, emergency control operations have received far more resources than the various elements of prevention, such as 1PM.

Research

Shifting from the current emergency focus to a preparedness and prevention approach will require that USAID tackle several types of research. Developing improved control programs requires a long-term, stable research program with sizable resources. The United States has a comparative advantage in conducting research of this type and Congress could encourage the U.S. Department of Agriculture (USDA), Environmental Protection Agency (EPA), Department of Energy (DOE), and the National Science Foundation (NSF), as well as USAID to support it. USAID could explore "twinning" programs between U.S. universities (land-grant and nonland grant col-

Box 4-B–Potential Congressional Oversight Questions and Congressional Policy Options: Implementing Integrated Pest Management

Accountability for the Past:

- Given that USAID's departure from its stated policy of IPM in the recent locust/grasshopper campaign was not fully justified, how might the agency have responded differently? Draw up several scenarios, including one without any pesticide use on the part of the U.S. Government.

Preparing for the Future:

- What research is USAID funding or planning in relation to alternative locust and grasshopper control methods, including projects on biological control, crop loss and economic injury levels, insect and weather forecasts, pesticide tests, etc.?
- How is USAID implementing IPM generally and in regard to locusts and grasshoppers specifically? How might USAID rely more on IPM during the next upsurge? What management changes might be necessary for this to occur?
- How does USAID set research priorities for programs related to Africa? What percentage of all USAID agricultural research funding directly relates to IPM? How do USAID's various bureaus coordinate research funding among themselves and with other donors?
- What efforts is USAID making to increase its technical capacity, generally, and in pest management, specifically? What staff hiring and training programs are underway at the missions and in Washington? What are their results?
- How, and at what costs, does USAID support agricultural extension and training in Africa; to what degree is IPM included in these programs? To what degree is IPM included in USAID-funded training of Africans in U.S. universities?
- What are USAID's plans regarding establishing policies and/or regulations for development and use of biological control agents and/or genetically engineered organisms in USAID-funded programs?

Congressional Options:

Option 1: *Congress could ask that USAID complete its delayed Pest Management Sector Review by an agreed on deadline.*

Option 2: *Congress could establish a Pest Management Task Force to determine and implement a revised USAID strategy. Also, this Task Force could: 1) commission an independent evaluation, perhaps by the National Research Council, of the recent locust and grasshopper campaigns and 2) form a standing Research Advisory Committee on grasshopper and locusts to backstop the U.S. Government's integrated pest management efforts.*

Option 3: *Congress could ask USAID to prepare a policy (e.g., a Strategy Statement, Policy Paper, Policy Determination, or other form, as appropriate) for using bioengineered organisms in U.S.-supported programs overseas.*

SOURCE: Office of Technology Assessment, 1990.

leges and universities) and developing country groups to conduct applied 1PM research and to develop and implement training in Africa.

Providing pesticides, aircraft, and spraying equipment consumed an inordinately large part of U.S. resources in the recent campaign. Still, the part of U.S. contributions currently designated for development of biological control for locust and grasshopper problems may be unwarranted because of biological control's unproven potential. So, important questions remain, especially regarding future priorities of U.S. research.

USAID needs improved inhouse technical expertise and this is especially important if USAID supports 1PM research programs. Deciding priorities among research projects and making specific funding decisions seems beyond the technical expertise currently within USAID. Without such expertise, USAID programs suffer in quality, become unduly influenced by political considerations, and lack continuity. While USAID has always relied on contracted expertise, many find current trends disturbing. USAID is known to have minimal technical capability in pest management (22). It seems that USAID has increasingly fewer career professionals with technical expertise and that the agency has problems retaining those it does have (132). Some experts contend that other donors, such as the Dutch, West Germans, and French, did a better job tapping their countries' technical expertise for grasshopper and locust problems.

Overall, U.S. Government agencies pay experienced scientists less than the private sector. In addition, USAID incentives reward those who plan–rather than carry out–programs. USAID field staff with general administrative experience and degrees in political science and economics are in a poor position to monitor the scientific merit of ongoing work related to scientific and technical issues (129). As a result, many layers of review by outside experts and other USAID staff in Washington are required, adding to the cost and time required to complete a given activity.

Research programs should take place in Africa as much as possible, include gender and family systems analysis, focus on the neediest farmers and herders, and tap indigenous knowledge as well as "frontier" technology. For example, efforts to implement an 1PM approach must include a sophisticated analysis of gender and family roles in agricultural production and the application of this analysis to proposed efforts. Women's agricultural roles display very different patterns in different African countries, and too often new technologies have increased their labor or decreased their share of the benefits.

Applying IPM to African realities will be challenging for American and European scientists. African scientists familiar with their environment, and able to speak the small farmers' language(s) may be better positioned to conduct this research than others. A small competitive grants program to support IPM-related research by Africans might encourage this type of work while bypassing the financial and management problems that were typical of the failed Permanent Interstate Committee for Drought Control in the Sahel (CILSS) 1PM project (136).

The Pest Management Task Force discussed above might designate a standing Research Advisory Committee, comprised of experts in 1PM, to assist USAID in deciding which research topics are most important to support. Members of the committee might assist USAID in designing realistic requests for proposals and selecting the researchers to carry them out. The committee, therefore, must be informed of: 1) the U.N. Food and Agriculture Organization (FAO) progress on research priorities regarding African grasshoppers and locusts, 2) African and European researchers' work on African insects, and 3) relevant research in Canada, Australia, and the United States regarding other types of grasshoppers and locusts. USAID could tap the modeling work of other Federal agencies and university scientists to improve forecasting. New or improved pest population and migration models are potentially very useful, especially for the African Migratory Locust, the Desert Locust, and Senegalese Grasshopper.

Training

Generally, training is cost-effective, helps strengthen institutions, and increases programs' sustainability. A clear need exists for training farmers in currently available 1PM methods, such as early identification of pests, safe pesticide use, and planting security crops. USAID should support such training for African extension agents, national crop protection services, and local farmers and herders. Moreover, USAID should review its current training programs to ensure that 1PM is included.

Bioengineered Organisms

Some bioengineered organisms are likely to have applications for pest management. The International Centre for Insect Physiology and Ecology (ICIPE) has already submitted a research proposal to USAID and other donors with plans to use such organisms. In the United States, a new and complex regulatory environment is developing related to the testing and use of bioengineered organisms involving EPA, USDA, the National Institutes of Health, the Food and Drug Administration (FDA), and several government advisory bodies on biotechnology (60). USAID should take the initiative to establish a policy framework for using such organisms overseas, while providing environmental and health safeguards. In the 1970s, USAID was forced by a lawsuit to develop appropriate guidelines for its development and use of pesticides. Today, USAID's policy response to the use of bioengineered organisms in pest management should not await a awsuit. Setting up protective regulations for testing and using additional types of biological control agents overseas might alleviate African, as well as American, fears such as those that led the government of Mali to cancel USAID-funded *Nosema* trials after considerable funds had been expended (99).

Using Pesticides Judiciously

Finding: USAID needs to examine carefully its pesticide research, evaluations, and technical ass& tance and then incorporate results so that pesticides are used more selectively. Training in safe and effective pesticide use should be a key component of donor crop protection efforts. Donor coordination will be essential if U.S. policies are to have the greatest impact.

Past locust and grasshop er control programs have left Africa with a fegacy of unsolved problems. USAID's response to date seems woefully inadequate in light of its own conclusions regarding pesticide disposal and health problems. In 1989, USAID spent only $50,000 for one health workshop. Congress could play an important role in changing this situation (box 4-C).

Judicious insecticide use includes a spectrum of activities such as developing and selecting less harmful insecticides, applying them more effectively and efficiently, and storing and disposing surplus supplies safely–all with greater regard to protecting people, their food and water, and the environment. An essential dimension is better balancing the costs and benefits of control. Another is improved surveillance and forecasting to allow more accurate and precise pesticide application on small target areas. Research to improve understanding of the insects' biology, such as pinpointing conditions and reasons for swarming behavior, can strengthen the foundation for these improvements.

Controversy and confusion reign on such issues as the best insecticides to use, the threshold at which to mount control, and the most vulnerable habitats. For example, the list of insecticides "approved" by USAID constantly changes, along with the rationale for selection and accompanying restrictions. These are researchable topics, however, and USAID is well-placed to conduct this type of research and then incorporate it into agency strategic and program planning. Also, USAID's programs probably would be more cost-effective if decisionmakers were more explicit regarding trade-offs and their consequences regarding insecticide use. For example, sampling spraying's effectiveness and impacts might allow fewer hectares to be treated. This could lead to decreased pesticide use and related expenses, e.g., for respraying and clean-up.

Training

Training in safe and effective pesticide selection and use is needed on all levels, from policymakers to individual farmers. Training and institutional development for African agricultural agencies (e.g., national crop protection services and agricultural extension services) should be a key component of donor crop protection strategies. Advantages might exist to making training part of broad-based efforts, e.g., USAID could evelop training programs for all pesticide applicators, whether spraying for malaria,

Box 4-C–Potential Congressional Oversight Questions and Congressional Policy Options: Using Pesticides Judiciously

Accountability for the Past:

- What has been the U.S. role in poor pesticide use (including site selection, storage, application, and disposal) in developing countries?
- What obligations–legal, ethical, and political–does the U.S. have to help correct such problems? How much might those efforts cost and how is USAID preparing, with other donors and African governments, to meet them?
- How is USAID addressing insecticide storage and disposal problems resulting from previous locust/grasshopper control efforts? What monitoring is underway for longer term health and environmental effects?
- Which U.S. procurement requirements increased costs, caused delays, or led to duplicate efforts in the recent campaigns? How much did these requirements add to U.S. costs?

Preparing for the Future:

- How will USAID use pesticides more selectively and efficiently the next time grasshopper and locust upsurges occur in Africa? How will USAID encourage other donors and Africans to do the same?
- What research is USAID supporting to develop safe and effective insecticides?
- What is the combined impact of pesticides used in agriculture and health programs on long term sustainable development? How is USAID addressing these concerns?

Congressional Options:

Option 1: *Congress could ask USAID to specify how it will use pesticides more selectively and efficiently and ameliorate negative health and environmental impacts.*

Option 2: *Congress could direct USAID to document in its environmental assessments how pesticide selection and targeting comply with EPA and U.S. Fish and Wildlife Service regulations and the Convention on International Trade in Endangered Species (CITES) regarding protection of critical habitats and threatened and endangered species.*

Option 3: *Congress could waive tied aid and selected procurement requirements for pest management in Africa to improve the speed, effectiveness, and efficiency with which insecticides are used. However, a new USAID strategy for more careful and selective pesticide use should be in place before granting such a waiver.*

SOURCE: Office of Technology Assessment, 1990.

grasshoppers, or other agricultural pests. This is likely to save money in the long-term and ensure a more integrated approach to pesticide use and documentation.

Preparedness

Preparedness can save time and expense in the long run. Information on insecticides in the

Programmatic Environmental Assessment (e.g., about which insecticides are more or less toxic to various habitats) and the Operations Guidebook is a good first step. USAID could take additional steps to alleviate confusion in the field regarding various insecticides and help its missions prepare for the next pest upsurges. Making one person in USAID/Washington responsible for maintaining up-to-date files on each insecticide used and providing clear information to missions would help missions be better prepared. Such a pesticide specialist could help USAID missions analyze technical information, apply what is known about the specific chemicals to their particular situation, and prepare or update country supplemental environmental assessments to fulfill Regulation 16.

USAID can implement its own staffs' suggestions to prepare for upsurges. For example, establishing more broadly-based rosters of highly qualified technical experts and experienced contractors who conduct aerial spraying (114) and maintaining up-to-date rosters could reduce delays in providing missions with assistance.

The concerted joint efforts of donors is likely to have greater impacts than single-handed U.S. efforts. For example, a need exists for a comprehensive evaluation of pesticide use in agriculture and disease control in developing countries. The U.N. agencies are the logical choice for this task because the U.N. World Health Organization is the major supporter of health-related spraying and FAO, for agricultural spraying. The U.N. Environment Programme would have an important role as well. The United States could contribute to this global effort in various ways. Either an external review panel or an interagency 1PM task force could analyze pesticide use in all USAID-supported work. Donor coordination also is important in order to provide African countries with consistent advice on regulations for safe and effective use of pesticides.

In some areas, USAID cannot implement measures to improve pesticide use without congressional action. U.S. procurement requirements regarding U.S. development assistance sometimes add to program rests, increase administrative burdens on Africans, and result in the use of inappropriate technologies (128). OFDA funds have built-in waivers from certain of these requirements, but pest problems rarely fit within OFDA's limit of providing assistance for 60 to 90 days. The recent campaign showed that prepositioning insecticides and equipment in Africa or Europe is rest-effective because it reduces air freight and enables a more timely response. Granting waivers to competitive bidding requirements for non-OFDA funds may help bring about a more efficient control program and help maintain such pre-positioned "pesticide banks" during upsurges. However, prepositioning insecticides might also facilitate even more widespread spraying. Pesticide banks would need careful maintenance to assure proper storage and this has not been done in the past.

U.S. Coordination and Support for African, U.N., and Regional Organizations

The United States does not administer foreign aid directly. Virtually every program requires the approval of African government and then depends on the participation of government or regional organimations to carry out U.S.-funded work. USAID, like others, increasingly recognizes that strengthening African organizations is essential for U.S.-supported efforts to be sustainable.

Within this context, a variety of organizations receive donor support, ranging from the national crop protection services to FAO and the regional African research and control organizations. A more coordinated approach to supporting these groups, as well as to supporting work in USAID and among U.S. agencies and other donors is likely to stretch scarce resources (box 4-D). To its credit, USAID actively promoted coordinating committees in each African country and participated in FAO and World Bank-sponsored meetings during the recent campaigns.

The Structure of U.S. Aid

Administrative responsibility for coordinating locust and grasshopper efforts within USAID shifted four times during the 4 years of the recent campaign (99). The lack of continuity in Washington caused changes in objectives, staff, programs, and funding restrictions. Also, changes in administrative responsibility, coupled with bureaucratic complexity, sometimes resulted in long delays in responding to requests from USAID

Box 4-D–Potential Congressional Oversight Questions and Congressional Policy Options: Coordination and Support for African, U.N., and Regional Organizations

Accountability for the Past:

- How does USAID support African national institutions in implementing sustainable pest management? How much 1986-89 funding went to national crop protection services in Africa? How much money went to U.S. firms and universities? What part of total U.S. assistance were these amounts?
- How have U.S. policy reform efforts affected African institutions and U.S. support for them? What impact did this have on locust and grasshopper control?
- On what basis has the disproportionate reduction of U.S. repayments of assessments to FAO v. other U.N. organizations been justified by the U.S. State Department? How does the State Department respond to FAO's contention that this hampered their locust and grasshopper programs?
- What benefits have been provided by USAID's "greenness maps" and at what cost? When will the capability to produce them be transferred to Africa? What will be the recurrent costs of such a program? How does this work relate to that of other groups doing similar work?

Preparing for the Future:

- How is USAID coordinating its grasshopper/locust efforts with FAO, other donors, and African countries regarding research, monitoring and surveillance, training, and insect control?
- What regional research and control organizations is USAID funding? What activities regarding integrated pest management and grasshopper and locust control are being supported and why?

Congressional Options:

Option 1: *Congress could ask that USAID set priorities regarding the nature, level, and timing of support for the various groups involved in locust and grasshopper research, monitoring, and control. As Congress oversees USAID's planning, it could ask USAID to identify related activities being conducted by others and describe how USAID-supported efforts complement, rather than duplicate, them.*

Option 2: *USAID could be encouraged to identify instances where congressional action constrains cost-effectiveness or subverts long-term work in favor of crisis management.*

Option 3: *Congress could examine the impact of the State Department's distribution of payments on FAO's locust and grasshopper programs, consider whether Congress' guidelines for payments to U.N. organizations are adequate, and determine whether the guidelines were applied satisfactorily by the State Department regarding U.S. payments to FAO.*

SOURCE: Office of Technology Assessment, 1990.

missions in Africa. Such administrative changes compounded lon -standing problems of coordination within USA&and other U.S. agencies.

Now that the insects are in recession, donors and others will be tempted to turn attention to other issues rather than carefully reassessing past programs and planning more sustainable, preventive approaches. Congress should ensure that this doesn't happen, although this may be the time for leadership of the U.S. effort to shift with new objectives. APHIS represents the United States on the FAO'S Desert Locust Control Committee; S&T/USAID has a leadership ole in the World Bank Special Program for African Agricultural Research (SPAAR) research task force and participates in a multidonor effort to prepare a global crop protection initiative (31). These agencies can play a larger role now, but their financial resources are relatively insignificant relative to other USAID bureaus and the U.S. State Department which administers funding for U.N. organizations.

Working with other countries' scientists should be a high priority because wasteful duplication already exists in high-priority technical areas. For example, USAID/U.S. Geological Survey (USGS) and World Bank efforts in early warning and forecasting seem tc parallel efforts by the Dutch, French, and FAO. Negotiations could eliminate the more costly overlaps and ensure that various components are integrated. An increased pro ortion of U.S. assistance might be allocated to multilateral organizations because the tied aid requirements of bilateral assistance contributes to duplication of donors' efforts. At a minimum, USAID should track the progress of others' planned or current projects before designing or funding similar ones. And, USAID should share its plans with other donors.

The Role of National Crop Protection Services

Finding: Many African national crop protection services are poorly equipped to take over a large part of locust and grasshopper monitoring and control or to develop integrated pest management strategies. Better-coordinated regional approaches are needed, but support for building individual crop protection services must be a significant part of donor assistance.

Africans must set their own agendas for development if efforts are to be most effective (132) and gradually assume more responsibility and leadership for programs. The national crop protection services in sub-Saharan Africa should gradually assume a greater role in leading the 1PM and locust and grasshopper control. In Northwest Africa, however, the national crop protection services already carry out this role.

Numerous avenues can increase the ability of African national crop protection services and other agencies within the Minis tries of Agriculture to do this, e.g., training, technical assistance, and institutional development. Currently, many crop protection services in the Sahel are handicapped by institutional constraints, jurisdictional problems, and/or the lack of infrastructure, trained personnel, and working equipment. They also lack information on alternative controls for insect pests. Donors can su port applied research by Africans to identify and test new methods, building on indigenous knowledge and practices where possible.

The situation differs among countries, however, so donors need to be flexible and use a variety of approaches. For example, the ability to monitor insects during recessions and to control outbreaks in remote breeding areas varies greatly. In some countries, the national crop protection service already undertakes these activities; in others, neighboring countries or regional organizations assist. The Northwest African countries monitor remote regions for locusts within their own borders. Generally, the four Maghreb countries have well-organized crop rotection services (sometimes with specialized locust control groups) and they can respond quickly to insect upsurges. They rapidly established locust control operations with a central headquarters, regional headquarters, and a number of technical and other committees during the recent campaigns.

The Department of Plant Protection and Locust Control of Somalia's Ministry of Agriculture recently proposed to strengthen its locust control service along these lines. The Ministry hopes to establish 9 units, with a total staff of 48, including 7 permanent or mobile field units, to monitor the Desert Locust in its summer and winter breeding grounds and control outbreaks as they begin. The Ministry requested funds for training, supplies (insecticides, application equipment, protective clothing), communication and transportation equipment (including spare parts and camping equipment), and improving pesticide storage facilities. The estimated budget was **$'720,000 for 3 years (l).**

On the other hand, Mali, whose national crop protection service is restricted to protecting croplands located mostly in the southern part of the country, allowed Algeria and Morocco to con-

duct ground operations in northern Mali so that swarms would not enter the Maghreb region. Also, Algeria and Morocco collaborated on surveillance and control in remote areas near their common border.

The national crop protection services, however, cannot be effective without working with additional national agencies. For example, 1PM requires, among other things, the cooperative effort of crop protection services with agricultural research and extension services, forest services, etc., to identify and use new pest management technologies.

The Role of African Regional Organizations, FAO, International Agricultural Research Organizations, and Local Groups

Finding: Regional groups have a distinct advantage in dealing with regional problems such as grasshopper and locust upsurges. African regional organizations must continue improving their management and financial support to reach their potential. FAO can lead in compiling da@ forecasting insect upsurges, and sponsoring meetings; the international agricultural research organizations in Africa can develop alternative control methods.

Finding: Local groups' participation in locust and grasshopper monitoring and control has significant advantages. Participation can be encouraged via the involvement of African nongovernmental organizations and donors' support for certain types of training, technical assistance, and pilot projects.

The recent locust and grasshopper upsurges demonstrated the importance of a variety of African groups and international organizations and highlighted their limitations. The resulting lessons learned have implications for improving U.S. development assistance to Africa

The sub-Saharan regional control groups- Joint Locust and Bird Control Organization (OCLALAV), Desert Locust Control Organization for Eastern Africa, and International Red Locust Control Organisation for Central and southern Africa–traditionally conducted control in areas beyond the reach of financially strapped national crop protection services. These groups are sorting out their mandates, capabilities, and resources, and deciding the relative amount of forecasting, surveillance, research, and control each will do and where they will do it. For example, OCLALAV'S members recently shifted responsibility for locust and grasshopper control from OCLALAV to their respective national crop protection services.

Donors have been instrumental in shaping these groups' reorganization and need to continue their involvement for their investment to pay off. At the same time, promoting institutional sustainability requires that African member nations take the lead in deciding mandates, organizational structure, amounts of members' dues, and programs. Deciding what activities and organizations to support is extremely difficult because of the changes underway. Donors need to be flexible and consider the whole picture-the relationship of the work of each regional organization to that of the others, FAO, other donors, and national crop protection services-before supporting particular activities.

For example, USAID's decision to fund the Center for Application of Agrometeorology and Hydrology for the Sahel (AGRHYMET) greenness maps has implications for similar programs funded by FAO as well as for relationships among African regional organizations. Also, decisions regarding OCLALAV's new responsibilities, Africans and donors must consider OCLALAV's work in relation to that of the other regional organizations associated with CILSS, especially AGRHYMET in Niamey Niger and the Sahel Institute in Bamako, Mali. AGRHYMET has been steadily increasing its technical forecasting capacity but, like Programme de Recherche Interdisciplinaire Français sur les Acridiens (PRIFAS), and USGS, has problems obtaining field data and disseminating reformation rapidly throughout the Sahel. The Sahel Institute, with trained scientists and up-to-date equipment, has the potential to conduct research and help implement some components of regional 1PM programs. CILSS' crop protection training department in Nigerma be able to implement other components. Also, CILSS maybe able to help mediate disputes between members that jeopardize survey and control efforts. However, CILSS' track record in 1PM and in resolving Member disputes has been disappointing.

In some cases, collaborative efforts between regional research and control organizations and national crop protection services would increase the effectiveness of both as well as the efficiency

with which donor funds are spent. Such efforts might include ada tive research; information exchanges; fellowsf ips, training, and personnel swaps; institutional "twinning," and sharing facilities.

Problems associated with disputes within nations and concerns between nations need to be alleviated to make pest control more effective. The regional control organizations' mandates do not include resolving internal disputes within countries nor differences between member and nonmember nations. The international Desert Locust task force proposed in 1988 by the countries of the Sahel and Maghreb maybe a model for joint ventures in other areas.

FAO–The questions surrounding the recent locust and grasshopper campaign will remain unanswered until some group becomes responsible for developing standard forms and procedures for use throughout the affected region, and then collects, compiles, and analyzes the data needed for forecasting, for monitoring insect populations, and for selecting control sites. In the United States, USDA collects the type of data needed and FAO, as the comparable international organization, could make similar efforts worldwide. This is likely to demand more resources, especially to develop a public database on pest levels, pesticides used, value of crops, etc.

Also, more coordinated responses are needed during upsurges and recessions. FAO has a long history coordinating these programs and is the only organization with the U.N. mandate and credibility to bring together the large number of donors and affected nations. For example, FAO is applying remote sensing and modeling to the locust problem with more continuity, cohesiveness, and scope than any other organization. So FAO is in a position to assist other donors divide responsibility among competing early warning and remote sensing programs and complement each others' efforts. FAO-sponsored regional conferences can continue to promote donor and African coordination on topics such as priority research and monitoring for migratory pests in remote areas.

The FAO/Emergency Centre for Locust Operations (ECLO) has demonstrated the technical expertise and the willingness to improve its work based on lessons learned during the recent locust and grasshopper campaign. FAO's current efforts to improve forecasting and implement "strategic control" with multinational teams are examples, and the organization's intention to fund these efforts during recessions deserves U.S. support. FAO must actively educate African, U.S., and donor policymakers on the necessity for laying groundwork during recessions for quicker, more precise responses during upsurges, for focusing on preventive work, and for supporting institutional development for these efforts to succeed.

Continued research is another long term need and FAO is moving ahead on at least two related projects. FAO and the U.N. Development Programme (UNDP) established a joint Scientific Advisory Committee in late 1989 to review research proposed for UNDP and donor funding. Also, FAO/ECLO published the first semi-annual Desert Locust Research and Development Register in July, 1989, identifying current and proposed research.

During the recent campaigns, FAO conducted control operations in some areas of sub-Saharan Africa, highlighting the inadequacy of regional and national African groups. In the short term, FAO'S direct participation m control probably will be needed but its goal should be to increase African capacity–regional and national–to mount their own efforts. FAO'S successful training and forecasting programs help achieve this. In addition, FAO can help donor and African participants devise ways to monitor the effectiveness of spraying and its impacts on health and the environment.

Several broader problems exist in providing U.S. support to regional and U.N. organizations. Pursuing foreign policy objectives sometimes has resulted in termination of USAID funding in the middle of long term development programs. Also, the various components of U.S. assistance themselves may have contradictory goals and constrain effectiveness. The results of some "policy reform" measures may gut other programs supported by donors, for example, by causing severe cut-backs in govemment employees (24).

The U.S. Department of State allocates funds to pay assessments and arrears due U.N. agencies, within general congressional guidelines. To some, it appears that the State Department's recent decisions have resulted in FAO'S bearing a disproportionate burden of money owed to all U.N. agencies (90). From 1985 to February 1990, the United States fell

$195 million behind in assessed payments to FAO. This amounts to nearly 70 percent of FAO's 1990 annual operating budget. In several instances, lack of funds affected FAO'S locust work adversely, e.g., field control staff were recalled when it appeared that FAO could not meet its payroll (91). In January 1990, the Bush administration requested nearly full funding of U.S. assessments and 100 percent payment for arrears, scheduled over 5 years.

Congress' guidelines for State's decisions are broad, emphasize political and financial considerations, and provide the State Department with wide latitude (see 124). Authorization for USAID and the State Department is done in different legislation by the House Foreign Affairs and Senate Foreign Relations Committees. The Senate and House Appropriations Committees set USAID and the State Department's budgets. In each chamber, however, two different subcommittees are involved. These various congressional actors differ in philosophy, reporting requirements, and the latitude they allow Executive Agencies. This constrains U.S. development efforts in Africa. Therefore, the various congressional subcommittees have a responsibility for coordinating their activities. For example, the two relevant Senate Appropriations Committee's Subcommittees: 1) Foreign Operations and 2) Commerce, Justice; and State; the Judiciary; and Related Agencies) could together examine the general congressional guidelines for funding U.N. agencies, their application to FAO, and their substantive adequacy.

International and Regional Agricultural Research Organizations–ICIPE and IITA are currently exploring biological and biorational controls for the Desert Locust and certain grasshopper species. ICIPE and DLCO-EA are among those testing the effectiveness of improved chemical insecticides.

These organimations should train thestaff's of Ministries of Agriculture and conduct joint research with national agencies as part of their research. These international organizations are likely to increase their research's chance of success, build support for their organizations, and increase national capacity in this way. Donors and member nations need to provide continuing support for these efforts to succeed. Also, they should ensure that regular communication takes place between the scientists at these organizations and those in Europe, the United States, and elsewhere in Africa.

Participation of Local Groups-Certain ground survey and control efforts in the recent campaigns were highly successful because of the participation of local groups of farmers and herders. Generally, farmers' groups helped conduct survey and control efforts near their croplands and herders scouted in more remote areas. Local groups' abilities to supply indigenous knowledge about pests and provide donors and others with specific information regarding local needs was less adequately tapped, however.

In the Sahel, farmer brigades were organized by national crop protection services assisted by USAID and UNDP funding. For example, farmer committees in Senegal and Gambia were trained to recognize the buildup of the Senegalese grasshopper and take action in or near their fields (19). Similar training was conducted in Mali, Burkina Faso, and Niger (71). Crop protection teams in Mali, aided by PRIFAS reports, identified areas of heaviest infestation, setup insecticide stores, and trained farmers to use manual dusters or sprayers to kill Senegalese grasshopper as they hatched. Similarly, Malian farmers, trained by plant protection and extension officers, monitored egg-laying and controlled Desert Locusts atthetime of hatching (71).

In countries where roads are poor or nonexistent, nomads on camels and farmers on donkeys can reach areas that the crop protection services cannot. In the Sudan, for example, crop protection services hired hundreds of herders on camels as local scouts to monitor insect buildup in inaccessible areas (121).

l-he more that local people and their organizations take part in decisionmaking about pest management, the less uncertainty exists regarding needs, objectives, and methods that are acceptable and sustainable, and the more likely projects are to capture important information (see box 4-E). Effective pest management that benefits low-resource farmers would build on, rather than disrupt, local means [illegible] food security. Farmers' approaches to crop protection have developed historically in ways highly integrated with their social goals and technical capabilities. For example, villages in the Lake Victoria region cooperate in protecting crops from birds by planting the same color and variety of crop at the same

Box 4-E–Integrating Farmers' and Scientists' Knowledge for Variegated Grasshopper Control

The Variegated Grasshopper is distributed throughout West and West-Central Africa. Occasionally explosive outbreaks occur, usually when eggs or adults escape control by natural enemies and when spring rainfall is higher than usual. Damage is especially significant because these grasshoppers eat cassava, maize, and beans–crops that farmers rely on to relieve food shortages.

In the early 1970s, parallel studies were undertaken in southern Nigeria after several, frequent, major outbreaks. Paul Richards and others examined local knowledge regarding this pest while the Centre for Overseas Pest Research in London undertook more conventional technical studies. Initially, experts suggested that highly organized control efforts, like those used for the Desert Locust, would be needed for this species. But the pest proved to be a more localized problem, with its life cycle completed within the space of a single farm, and amenable to less centralized control.

Richards found that farmers were well aware of the insect's ecology and, in a few cases, their suggestions regarding effective control anticipated the findings of the London researchers: to mark and dig up egg-laying sites on each farm. Other findings of the research team were beyond the scope of farmers, e.g., ones requiring laboratory facilities.

Also, Richards found that research conducted by outside scientists would have been more useful and cost-effective if farmers' knowledge regarding grasshopper ecology had been considered from the outset. Instead, the scientists apparently reconstructed information that was already available and missed other data that farmers could have provided, e.g., on the relative significance of damage to minor but locally significant crops and oral history regarding the timing and severity of previous grasshopper plagues.

The knowledge possessed by farmers and by London scientists and others was complementary. Scientists provided certain biological details but farmers knew the social context of the problem. Farmers were able to destroy egg-laying sites on individual farms and had already attempted to use this method with limited success. Others, however, such as extension agents, were needed to coordinate community efforts for the program to succeed. Once egg-laying sites were destroyed on blocks of farms, grasshopper numbers were reduced by 70 to 80 percent.[a]

[a]W. Page and P. Richards, "Agricultural Pest Control by Community Actions: The Case of the Variegated Grasshopper in Southern Nigeria," *African Environment*, 1977, vols. 2 & 3, pp. 127-141.

SOURCE: Paul Richards, *Indigenous Agricultural Revolution* (London: Hutchinson & Co., 1985), pp. 146-149.

time, thus spreading risk among all the farmers. Government and donor planners would benefit from studying such approaches Highly centralized research and management tends to exclude participation by local groups. And most grasshopper and locust control efforts are highly centralized.

The most serious limitation to increased farmer and herder participation is lack of information about improved pest management. Generally, pest management networks do not exist, people have little access to appropriate literature, they are not literate, etc. Crop protection services and others can increase their ability to reach larger numbers of farmers and herders by working with existing village or farmer organizations or other nongovernmental organizations in the area. The African Development Foundation (ADF) and others have demonstrated that local intermediary groups can play an important role in development programs (130). Many such groups exist within

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African countries, including local church groups, that have the ability to mobilize or communicate with people in an area. Information disseminated through these types of groups may be quite effective. For example, one ADF-funded project decreased use of lindane after dancers and a local healer warned people of its&n&m.

Funding Implications

Some adjustments of U.S. bilateral and multilateral funding maybe necessary to ensure that the most effective pest management is undertaken. These can be obtained by:

- reapportion nment within current appropriations levels,
- changes to financial structures, such as USAID's Development Fired for Africa, created in 1988, and
- appropriations of additional funds.

Reapportioning Current Appropriations

Some monies needed to support improvements in USAID's grasshopper and locust work may come from internal shifts of funds because the Agency is no longer funding massive control efforts. For example, on-going programs, such as institutional development of African agricultural organizations, may incorporate 1PM or improved insecticide use without requiring additional funds.

Congress maywant to encourage USAID to allocate additional existing agricultural funds to pest management generally and IPM specifically. Pest management received a declining share of the Bureau for Science and Technology's agricultural budget in recent years. From fiscal years 1977 to 1988, pest management received an overall average of 5.8 percent of S&T/agriculture funds, but in 1986 this sector only received 1.0 percent; in 1987,3.2 percent; and, in 1988, 1.8 percent (116). The amounts of funds allocated worldwide were small: $340,000 in 1986; $900,000 in 1987; and $520,000 in 198& This trend, coupled with reduced USAID funding to agriculture in general, means that few U.S. development assistance funds are being spent on long term pest management.

Changes to Financial Structures

Congress replaced USAID's functional accounts with the Development Fund for Africa in 1988 to provide USAID with increased flexibility and to make furiding more efficient. Congress could evaluate the impact of the Development Fund. Early indications are that agricultural funding decreased relative to other sectors as a result, as did pressure to fund activities with quick, visible results. If so, the Development Fund for Africa may neither be achieving its goals, nor be able to seine as a model for other programs.

Appropriations of Additional Funds

There is no doubt that new efforts would require new appropriations. What is not clear is how much these efforts would cost.

Implementing IPM for locusts and grasshoppers and other pests would require funds for planning, training, research, and coordination. Also, funding would be required for preventive work, e.g., monitoring pest populations (as advocated by USAID, FAO, other donors, and affected countries) and improving forecasting systems. For example, establishing the proposed International Task Force for ground monitoring and control of the Desert Locust in remote areas in the Sahel and continuing to produce greenness maps would require new or continued funding. The price-tag for such new efforts is not clear, but USAID will need to estimate some of these costs while planning the AELGA follow-on project. Congress may want to ensure that all components of USAID's follow-on work are considered together.

Providing equipment and supplies can be an important part of efforts to strengthen local, national, and regional African institutions. Some relatively inexpensive items may increase the capacity of national crop protection institutions to monitor insect populations, e.g., fax machines, radios, and spare parts. Other items—such as satellite receiving stations and major research proposals—are far more costly.

Appendixes

Appendix A-Acronyms and Glossary

Acronyms

AELGA	–Africa Emergency Locust/Grasshopper Assistance (USAID project)
AFR	–Africa Bureau (USAID)
AGRHYMET	– Center for Application of Agrometeorology and Hydrology for the Sahel (Niamey, Niger, affiliated with CILSS)
ANE	–Asia/Near East Bureau (USAID)
APHIS	–Animal and Plant Health Inspection Service (USDA)
ARTEMIS	–Africa Real Time Environmental Modeling Using Imaging Satellites (FAO)
BHC	–Benzene hexachloride, a persistent chlorinated hydrocarbon pesticide
CDIE	–Center for Development Information and Evaluation, USAID
CILSS	–French acronym for the Permanent Interstate Committee for Drought Control in the Sahel (a regional organization of nine nations: Burkina Faso, Cape Verde, Chad, The Gambia, Guinea Bissau, Mali, Mauritania, Niger, and Senegal)
DDT	– Dichloro diphenyl trichloroethane, a persistent chlorinated hydrocarbon pesticide
DLCO-EA	– Desert Locust Control Organization for Eastern Africa (Addis Ababa, Ethiopia)
DOE	–U.S. Department of Energy
ECLO	–Emergency Centre for Locust Operations (FAO)
EIS	–Environmental impact statement, as required by the National Environmental Policy Act of 1%9
EPA	–U.S. Environmental Protection Agency
EROS	–Earth Resources Observation Systems (USGS)
FAO	–Food and Agriculture Organization of the United Nations
FEWS	–Farnine Early Warning System (USAID)
GIEWS	–Global Information and Early Warning System (FAO)
GTZ	–German acronym for the German Agency for Technical Cooperation
ICIPE	–International Centre for Insect Physiology and Ecology (Nairobi, Kenya)
ICRISAT	–International Crops Research Institute for the Semi-Arid Tropics
IITA	–International Institute for Tropical Agriculture (Ibadan, Nigeria)
1PM	–Integrated Pest Management
IRLCO-CSA	–International Red Locust Control Organisation for Central and Southern Africa (Ndola, Zambia)
NOAA	–National Oceanic and Atmospheric Administration (U.S. Department of Commerce)
NSF	–U.S. National Science Foundation
OCLALAV	–French acronym for the Joint Locust and Bird Control Organization (Dakar, Senegal)
OFDA	–Office of Foreign Disaster Assistance (USAID)
OICD	–Office of International Cooperation and Development (USDA)
OTA	–Office of Technology Assessment, U.S. Congress
PRIFAS	–Programme de Recherches Interdiciplinaire Francais sur les Acridiens du Sahel (unit of the French research agency CIRAD that studies locusts and grasshoppers of the Sahel).
S&T	–Bureau for Science and Technology (USAID)
SAS	–Surveillance des Acridiens au Sahel, a French network for collecting field observations on locusts and grasshoppers in the Sahel (PRIFAS)
SPAAR	–Special Program for African Agricultural Research (World Bank)
SWA	–Office of Sahel/West Africa (USAID/AFR)
ULV	–Ultra-low volume (spraying application)
UNDP	–United Nations Development Programme
USAID	–U.S. Agency for International Development
USDA	–U.S. Department of Agriculture
USFS	–U.S. Forest Service (USDA)
USG	–U.S. Government
USGS	–U.S. Geological Survey (U.S. Department of the Interior)

Glossary

Band: Cohesive group of gregarious hoppers that march together in daytime and roost at night

Fax: Also, telefax, facsimile; method for electronic transmission of documents

Fledgling: A sexually immature adult locust or grasshopper that is able to fly; developmental stage after the last molt

Grasshoppers: Insects with powerful legs adapted for jumping, belonging to the scientific order Orthoptera; in this report refers to a small number of species of aggregating grasshoppers that can form gregarious bands and swarms

Gregarious Phase: Period when locust populations form large, dense groups resulting from crowding; involves behavior, color, then shape and physiological changes in the insects

Hopper: Second stage of locusts' life cycle (between egg and adult) comprised of several instars and characterized by insects' inability to fly

Instar: Growth period between times that grasshoppers and locusts molt

invasion Areas: Areas, larger than outbreak areas, in which locust and grasshopper bands and swarms can be found after gregarization

Locusts: Insects within the scientific order Orthoptera, superfamily Acridoidea; distinguished from most grasshoppers primarily by ability to form gregarious bands and swarms

Maghreb: Area north of the Sahara desert and east of Egypt; countries of Algeria, Morocco, Libya, and Tunisia

Molt: Process by which hoppers shed their skin periodically, usually occurring five times during the second stage of the insects' life cycle

Outbreak: Marked increases in locust or grasshopper populations leading to the appearance of gregarious groups; occurs frequently and may mark the beginning of an upsurge

Outbreak Areas: permanent breeding and gregarization areas that have been identified for major locust species except Desert Locusts; very much smaller than invasion areas of these species

Plague: Occurrence ofmanybands and swarms over a large area in different regions at the same time

Recession: Period when gregarious bands and swarms of locusts and grasshoppers are rare, solitary insects predominate

Recession Area: Area that solitary Desert Locusts occupy at low density; the vast central, drier area of Desert Locust distribution, within its invasion area

Sahel: Geographically, the semiarid areas of the Sahara Desert's southern edge. Politically, the nine West African countries that are CILSS members.

Solitary Phase: Period when locusts and aggregating grasshoppers live as individuals, when populations are low-density and scattered

Swarm: Cohesive group of gregarious adult locusts or grasshoppers that fly together, usually during the day, and rest at night

Upsurge: Buildup of bands and swarms, especially outside of outbreak areas; infrequently marks the start of a plague

Appendix B-List of Contractor Papers, Contracted Analysis, and Workshop Participants

Contractor Papers

"Locusts and Grasshoppers in Africa and the Middle East"
Author: Dale G. Bottrell
Department of Entomology
University of Maryland
College Park, MD

"The Prospect for Equitable and Sustainable Desert Locust Control in A Changing African Environment"
Author: Dean L. Haynes
Department of Entomology
Michigan State University
East Lansing, MI

"Social and Ethical Issues in Desert Locust Control for Africa"
Author: Paul B. Thompson
Philosophy Department
Texas A&M University
College Station, TX

Contracted Analysis

"Locusts in Africa and the Middle East: Summary of Responses to OTA Questionnaire"
Author: Dale G. Bottrell
Department of Entomology
University of Maryland
College Park, MD

Workshop Participants

Dale G. Bottrell, Author
Dean L. Haynes, Author
Paul B. Thompson, Author
Kathleen M. Desmond, Contractor
Roger C. Herdman, OTA
Walter E. Parham, OTA
Phyllis N. Windle, OTA

Appendix C-OTA Survey Form

INFORMATION FORM FOR LOCUST EXPERTS

Office of Technology Assessment, U.S. Congress

Your Name ____

The Country/s or Region/s with which you are familiar and upon which you have based the following information.

____

Please provide a brief description of your experience related to locusts and your current position.

PART A. THE CURRENT SITUATION

1. **How would you rate the intensity of the locust problem in the country or region with which you are familiar, over the last several decades? Please circle one response for each time period.**

1950-59	Very Serious	Serious	Insignificant	Not Present
1960-69	Very Serious	Serious	Insignificant	Not Present
1970-79	Very Serious	Serious	Insignificant	Not Present
1980-88	Very Serious	Serious	Insignificant	Not Present

2. **If you detect a serious or very serious locust problem now, please identify, with numbers 1-3, the frost, second, and third most important locust species involved.**

______	Desert locust (*Schistocerca gregaria*)
______	African migratory locust (*Locusta migratoria*)
______	Red locust (*Nomadacris septemfasciata*)
______	Other ______________________
______	______________________

3. **How would you judg the geographic distribution of the locust infestations in the areas with which you are familiar over the last sevenal decades? Please circle one response for each time period.**

1950-59	Not Significant	Local	Widespread	Large/Regional
1960-69	Not Significant	Local	Widespread	Large/Regional
1970-79	Not Significant	Local	Widespread	Large/Regional
1980-88	Not Significant	Local	Widespread	Large/Regional

4. **Please comment on any trends in locust problems that you see.**

5. **Is desertification or local weather patterns intensifying locust problems in this area? Why/W@ not?**

6. **Do people in the region with which you are familiar eat locusts?**

   Yes No

7. **Please add anything else that you feel U.S. policymakers, donor groups, or researchers should know regarding the locust situation in the area with which you are familiar.**

PART B. EFFECTS OF THE LOCUST INFESTATION

1. **Please list the crops (export and/or subsistence crops) that are principally affected by locusts, the stage/sat which locusts attack them, an your estimate of the percentage of the country or region's crop seriously enough affected by the current locust infestation to cause a significant drop in normal crop yields.**

Crop	Stage	Percentage of Crop Affected

2. Please estimate, **if you can, the** average **national per hectare yield of these crops, with and without locust** infestation in the country or region with which you are familiar. (Include units)

Crop	Average Yield Without Locust Infestation	Average Yield With , cust Infestation

3. **What are the social consequences of locust infestation in the region?**

4. **Please list the other types of lands principally affected by locusts and estimate, if you can, the percentage of the area seriously enough affected by the current locust infestation to cause a significant threat to livestock production, tourism, soil Conservation, or other important uses of non-croplands.**

Land Use	Percentage of Area Affected
Grazing lands	
Parks and protected areas	
Other:	

5. **Please add anything that you feel U.S. poliymakers, donor groups, or researchers should know regarding the effects of locusts in the country or region with which you are familiar.**

PART C. CONTROL EFFORTS

1. **Please list the national agencies that conduct locust control programs in your country or region and the international organizations that support local control programs.**

2. Please list **the insecticides that are used presently and were used in the past for locust control in these programs, along with their application method (e.g., ground spraying).**

Pesticides Used Currently	Application Method/S
Pesticides Used in the Past	**Application M e -**

3. **On what basis are decisions made to apply pesticides, e.g., surveys, previous outbreaks, etc.?**

4. **How are pesticides provided (e.g., from the private sector, from donors)?**

5. **How are excess pesticides disposed of?**

6. **Have side effects from these pesticides been detected? If so, please list them.**

7. **How are safety issues addressed?**

8. **Please list the principle locust controls used by subsistence farmers in this area. Indicate whether these are used predominantly by men, women, or both.**

9. **Are village level groups taking part in locust control efforts in this area? If so, how?**

10. **What nonpesticide locust control methods are known, available, and/or encouraged in the area with which you are familiar? Please list these.**

11. **What promising new technologies are available now or might be available in the future for controlling locusts in this area?**

12. **How effective do you consider various locust control efforts to be? Very effective (vE), Somewhat Effective (SE), Ineffective (I), Don't Know (DK). Please circle one response.**

International efforts	VE	SE	I	DK
National Efforts	VE	SE	I	DK
Local efforts	VE	SE	I	DK

13. **Please add anything that you feel U.S. policymakers, donors, or researchers should know regarding locust control efforts in the area with which you are familiar.**

PART D. PLANNING FOR THE FUTURE

1. **What are the most crucial needs for dealing more effectively with potential future locust infestations in the region with which you are familiar? Please circle all that apply and feel free to add others.**

Personnel:

laborers, trained technicians, scientific researchers,

Infrastructure:

facilities, roads, cars, trucks, motorcycles, airplanes, spray equipment, chemical supplies, pesticide disposal sites,

---

Institutions:

research laboratories, field research sites, regulations for pesticide use,

---

Information:

weather forecasts, locust monitoring, locust early-warning systems, locust status reports from neighboring countries,

---

2. How important would locusts rate if you listed the 10 most serious pests in the country or region with which you are familiar? Please circle one rating (l-most serious; 10-least serious).

1 2 3 4 5 6 7 8 9 10 lower than 10

3. Please list the three most serious needs this area faces related to current locust problems.

________ ________ ________

4. Please list the three most serious needs this area faces in all types of agricultural research.

________ ________ ________

5. Please list the three most serious agricultural research needs related specifically to locust problems.

________ ________ ________

6. How could United States' foreign aid assist most effectively in current locust problems?

7. Please characterize the proportion of various types of locust activities underway now in the area with which you are familiar (use percentages). Then please provide what you would see as the ideal proportion.

	% of C- Effort	% of Ideal Effort
Crisis Management (e.g., spraying locusts)	____	____
Relief Activities (e.g., providing food for affected areas)	____	____
Outbreak Prevention (e.g., long-term entomological research)	____	____
______(other)	____	____
Total	100%	100%

8. Please add anything that you feel U.S. policymakers, donors, or researchers need to know regarding planning for future locust control programs in the area with which you are familiar.

PARTE. METHODS

1. What degree of certainty do you have in the information for the country or region with which you are familiar? DK=don't know; VU = very uncertain; U = uncertain; C=certain; VC = very certain. Please circle 1 response.

Part A. Data on Current Locust Infestation

a. Measures of the intensity and distribution of locust outbreaks.

DK VU u c V c

b. Measures of the effects of desertification and weather on outbreaks.

DK VU u c V c

Part B. Estimates of the Effects of the Current Locust infestation.
a. Percentage of crops affected

DK VU u c VC

b. Percentage of noncroplands affected.

DK VU u c Vc

Part C. Your estimate of the effectiveness of locust control efforts.

DK VU u c Vc

Part D. Planning for the Future
a. Likelihood of improved locust control technologies

DK VU u c Vc

b. Consensus on agricultural research needs related to locusts

DK VU u c Vc

2. **May we contact you for further evaluation of your responses for our report? Please circle one response.**

Yes *No*

We appreciate the time you have spent in completing this form. Please return it by February 6, 1989 to:

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Appendix D-List of Survey Respondents

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Appendix F–Recommendations From Three Recent Reports on Pest Management in Developing Countries

Several recent studies provided comprehensive recommendations for USAID and for Congress on pest management generally and locust and grasshopper programs specifically. The recommendations from three of these are included below because Congress can find a number of important options among the recommendations:

I. Programmatic Environmental Assessment of Locust and Grasshopper Control in Africa/Asia (1%9)

II. Africa Emergency Locust/Grasshopper Askance (AELGA) Mid-Term Evaluation (1989)

III. Report of the Committee on Health and Environment (1988)

SECTION I

RECOMMENDATIONS FROM THE PROGRAMMATIC ENVIRONMENTAL ASSESSMENT OF LOCUST AND GRASSHOPPER CONTROL IN AFRICA/ASIA[1]

Required Precondition

This report included 38 recommendations, grouped according to priority. It recommended that:

1. USAID continue its involvement in Locust and Grasshopper Control. Operationally, the approach to be adopted should evolve toward one of Integrated Pest Management (IPM).

Top Priority, for Immediate Implementation

2. An inventory and mapping program be started to determine the extent and boundaries of environmentally fragile areas.

3. A system for dynamic inventory of pesticide chemical stocks be developed.

4. USAID take an active role in assisting host countries in identifying alternate use or disposal of pesticide stocks. Refer to Recommendation 14.

5. FAO, as lead agency for migratory pest control, be requested to establish a system for the inventory of manpower, procedures, and equipment.

6. There be no pesticide application in environmentally fragile areas and human settlements.

7. Pesticides used be those with the minimum impact on nontarget species.

8. Pre- and post-treatment monitoring and sampling of sentinel organisms and water and/or soils be carried out as an integral part of each control campaign.

9. One of the criteria to be utilized in the selection of control techniques be a minimization of the area to be sprayed.

10. Helicopters be used primarily for survey to support ground and air control units. When aerial treatment is indicated, it should only be when very accurate spraying is necessary, such as close to environmentally fragile areas or for localized treatment.

11. Whenever possible, small planes be favored over medium to large two-or four-engine transport types. In all cases, experienced contractors will be used.

12. Any U.S. Government-funded locust/grasshopper control actions, which provide pesticides and other commodities, or aerial or ground application services, include technical assistance and environmental assessment expertise as an integral component of the assistance package.

13. All pesticide containers be appropriately labeled.

High Priority, For Implementation When Resources Are Available

14. USAID provide assistance to host governments in disposing of empty pesticide containers and pesticides that are obsolete or no longer usable for the purpose intended.

15. USAID support the design, reproduction, and presentation of public education materials on pesticide safety (e.g., TV, radio, posters, booklets). This would include such subjects as, safely using cost effective pesticides, ecology, pest management of locusts and grasshoppers, and the hazards of pesticides. The goal would be to help policymakers and local populations recognize potential health problems related to pesticide applications.

[1] TAMS Consultants, Inc. and the Consortium for International Crop Protection, *"Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment,* Executive Summary and Recommendations (Washington, DC: USAID) contractor report prepared for the U.S. Agency for International Development, March 1989, pp. EXSUM-34-53.

16. Training courses be designed and developed for health personnel in all areas where pesticides are used frequently.

17. Each health center and dispensary located in an area where pesticide poisonings are expected to occur be supplied with large wall ters in which the diagnosis and treatment o specific poisonings are depicted. The centers and dispensaries should also be povided, prior to spraying, with those medicines and antidotes required for treatment of poisoning cases.

18. Presently available tests for monitoring human exposure to pesticides be evaluated in the field This includes measurement of cholinesterase levels in small samples of blood as a screening test

19. The specifications developed for USAID purchase of locust/grasshopper insecticides be adapted for all insecticides.

20. Pesticide container specifications be developed.

21. *Nosema* and other biological agents such as Neem be fieldtested under African and Asian conditions in priority countries.

22. A comprehensive training program be developed for USAID Mission personnel who have responsibility for control operations. This will involve a review of existing materials and those under development, in order to save resources.

23. Local programs of training be instituted for pesticide storage management, environmental monitoring and public health (see Recommendaion 16).

24. When technical assistance teams are provided, they be given short term intensive technical training (including language, if necessary) and some background in the use and availability of training aids.

25. Field research be carried out to generate badly needed economic data on a country-by-country basis.

26. No pesticide be applied unless the provisional *economic* threshold of locusts or grasshoppers is exceeded.

27. USAID provide assistance to host countries in drawing up regulations on the registration and management of pesticides and the drafting of environmental policy.

28. A pesticide use inventory covering all treatments in both agricultural and health programs be developed, on a country-by-country basis.

29. USAID produce a regularly updated pesticide handbook for use by its staff.

30. That technical assistance, education and training, and equipment be provided crop protection services of host countries with a view to making the services eventually self sustaining.

Desirable, But Less Urgent

31. More pesticide storage facilities be built. Until that occurs, emergency supplies be pre-positioned in the United States.

32. USAID make a decision as to whether to continue funding forecasting and remote sensing or utilize the FAO's early warning program.

33. A series of epidemiologic case-control studies, within the countries involved in locust and grasshopper control, be implemented in areas of heavy human exposure to pesticides.

34. Applied research be carried out on the efficacy of various pesticides and growth retardants and their application.

35. Applied research be carried out on the use of Neem as an antifeedant.

36. Research be carried out to determine the best techniques for assess@ the impacts of organophosphates used for locust and grasshopper control "in relation" to the use of these and other chemicals for other pest control programs.

Procedures To Accelerate Implementation Of' All Recommendations

37. USAID, on the basis of the previous Recommendations, develop a plan of action with practical procedures to provide guidance in locust/grasshopper control to missions in the field.

38. Detailed guidelines be developed for USAID to premote common approaches to locust and grasshhopper control and safe pesticide use among UN Agencies and donor nations. Coordination of efforts is becoming increasingly important because of the increasing number and magnitude of multilateral agreements and follow up efforts in subsequent years by various *donors.*

SECTION II

RECOMMENDATIONS FROM THE AFRICA EMERGENCY LOCUST/GRASSHOPPER ASSISTANCE (AELGA) MID-TERM EVALUATION[2]

Set 1: Emergency Control Operations

Emergency control operations succeed or fail on the efficacy of their logistics.

a. **Implement, either directly through the AELGA project or indirectly through the USDA Resource Services Support Agreement (RSSA), short-term (6-7 months) technical assistance in entomology to the missions that still lack this expertise.**

b. **Expand the pesticide bank to include other acceptable chemical and biological agents besides the carbaryl and malathion that are presently available.**

c. **Maintain a current file of firms that provide aerial spraying services and pesticide transport, with aircraft type, availability and cost.**

d. **Continue the present RSSA with USDA for the provision of greenness maps and for the provision of short-term technical assistance in map interpretation.**

e. **Continue the present RSSA with USDA for the provision of long- and short-term technical assistance for locust surveys and control operations.**

f. **Work with the appropriate African regional organizations, such as OCLALAV and CILSS, for the conclusion of interstate agreements on flyer rights for the movement of survey aircraft, fly over rights for cross-border locust control operations, the transport of pesticides and other agents among member states, and other such regional issues that have impeded locust control from time to time.**

Set 2: Development Actions for the Short-term

AELGA should provide whatever assistance that USAID mission require in their locust control programs. Training courses are more traditional institution-building activities. The topics for these training courses, which must emphasize field-level concerns are (in addition to the courses now being delivered by AELGA on locust and grasshopper identification, ultra-low volume aerial application and crop-loss assessment):

a. **Management of logistical operations, for supervisors.**

b. **Health concerns for locust control operations, for health personnel and locust control supervisors, as well as for pesticide handlers.**

c. **Strengthening of farmer brigades and of the crop protection services terrestrial teams.**

d. **Techniques for proper storage of pesticides and their containers.**

e. **Cumulative effects of pesticide use on the environment, a regional conference for senior government personnel.**

Set3: Long-term Actions for Locust Control Forecasting, Institution-building and Research

The [AELGA] project should focus its efforts during its remaining life on those longer-term development aims that have the potential of assisting future locust control efforts and that complement ongoing activities.

a. **Work with the international organizations, in particular the FAO, that are developing a locust forecasting capability.**

b. **Work through USAID/AFR/SWA with African regional organizations, such as OCLALAV, CILSS (INSA), and AGHRYMET, in, respectively the development of training materials and the coordination of crop protection services (which are charged with locust survey and control); the coordination of logistical considerations (such as flyer rights); and, the provision of meteorological information. . . . While it maybe necessary to continue to fund these activities through the FAO in the short-term, that organization must be required to collaborate closely with the regional organizations and a portion of the FAO grant moneys could be earmarked for this purpose.**

c. **Coordinate the work being done by bilateral USAID missions in locust control and crop protection and facilitate the improvement of locust survey and control activities in national crop protection services, as requested by the concerned USAID missions.**

d. **Develop the present economic cost/benefit analysis based on crop loss assessment for deciding when spraying operations are necessary.**

[2]Tropical Research and Development, Inc. "Africa Emergency Locust/Grasshopper Assistance (AELGA) Mid-Term Evaluation," contractor report prepared for U.S. Agency for International Development (Washington, DC: USAID), July 15, 1989.

e. Institute an environmental monitoring (perhaps in conjunction with other monitoring efforts) and health safety program (e.g., application procedures, drum disposal methods).

Set 4: Considerations in (AELGA) Project Management

a. Retain AFR/Office of Technical Resources as the project location within AID.

b. Take immediate steps to put in place the implementation mechanisms suggested in Recommendation Set 1 above.

c. Design a longer-term development program along the lines of Recommendation Sets 2 and 3.

d. Review the use of agreements with USG and the international agencies for emergency operational activities such as the *procurement* of services and commodities for the control of locust outbreaks.

e. Computerize the project monitoring system to track project activities.

f. Exert closer control of all research activities to ensure that the activities are relevant to AELGA needs, responsive to mission concerns, and integrated with host country agency activities.

g. An additional intern be funded through USDA/OICD RSSA to assist the present project manager and long-term technical adviser.

Set 5: Major Design Considerations in Locust Control Programs

Locust control is a long-term problem that requires international cooperation.

The recent and present emphasis on locust control through the actions of national crop protection services' will, if successful, provide only a partial solution to the long-term problem.

- Institutional strengthening of the national crop protection services is fundamentally necessary for locust control, particularly in agricultural areas.
- Nonetheless, a regional problem requires a regional response.
- . . .USAID's locust control strategy must remain flexible.. .to work with and through the FAO to carry out necessary locust forecasting and control operations while, at the same time, building national and regional response capability=
- While the mission buy-in mechanism can work successfully for normal development activities, it is ill-adapted for continued emergency disaster plarming and implementation.

Set 6: The Need for a Follow-on Project

a. Develop a follow-on umbrella pest management, crop protection, or food semity project that will continue the on-going activities of locust control and, at the same time, strengthen the crop protection agencies in the concerned countries so that they are better able to assist small producers in achieving the benefits from improved agriculture that are now accruing.

SECTION III

RECOMMENDATIONS FROM THE REPORT OF THE COMMITTE ON HEALTH AND ENVIRONMENT[3]

The Foreign AssistaneeAppropriations Act of 1987 charged USAID with forming a Committee on Health and Environment to examine opportunities to assist developing countries in the proper use of agricultural and industrial chemicals. The Committee, with help from the Conservation Foundation, submitted these 6 major recommendations to USAID, along with detailed suggestions for implementation:

1. USAID and other donors should work to strengthen and increase the number of constituencies in multiple sectors and levels of society which actively support safe and environmentally sound use of pesticides and industrial chemicals in developing countries.

'Conservation Foundation, *Opportunities to Assist Developing Countries in the Proper Use of Agricultural and Industrial Chemicals,* vol. 1, Final Report (Washington, DC: The Conservation Foundation), Feb. 18,1988.

2. **USAID should enhance the effectiveness of its agricultural and health programs that affect or involve pesticide or chemical use.**

3. **USAID should increase its use of Integrated Pest Management (IPM) significantly, with the goal of making IPM its primary pest management approach. Achieving this goal will require improved implementation and more support for research and training, and would have a catalytic effect on other donors.**

4. **In cooperation with other U.S. agencies and the private sector, USAID should prepare a long-term plan for its role in preventing and mitigating problems associated with activities involving industrial chemicals in developing countries.**

5. USAID should report to Congress every two years, beginning in 1989, on its progress toward implementing the recommendations in this report and on future opportunities to address pesticide and chemical issues in developing countries.

6. *Congress* should provide clear policy guidance to U.S. Government agencies regarding the provision to, and use of, agricultural and industrial chemicals in developing countries. The Executive Branch should then implement that policy in a consistent fashion.

Appendix Preferences

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11. Bourasset, Arnaud-Xavier and Michel Launois, "La Logique d'Organisation d'un Service de la Protection des Vegetaux au Sahel," Serie Speciale No. 1 (Montpelier: CIRAD/PRIFAS) decembre 1988.

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