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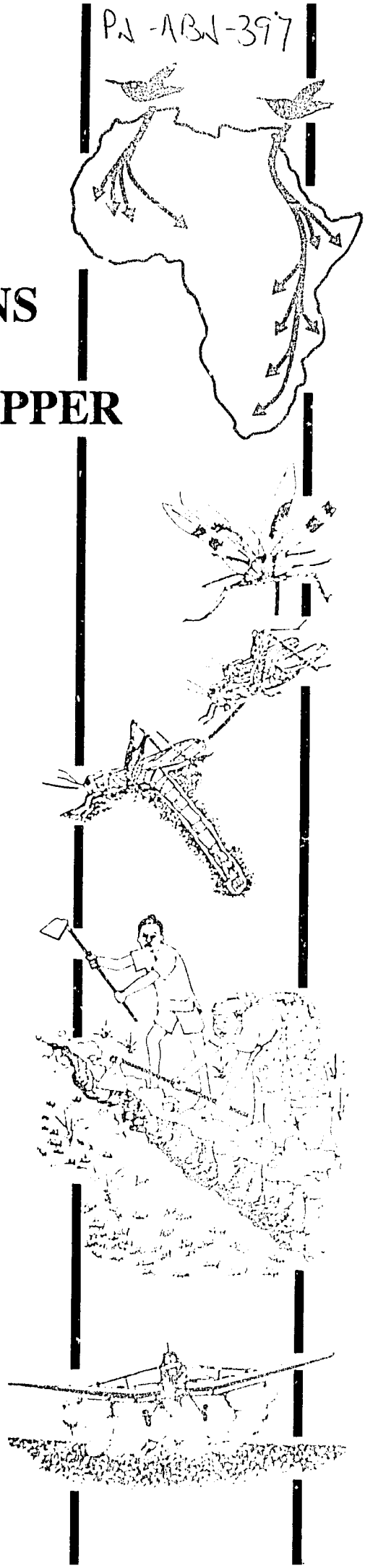
Review of

ENVIRONMENTAL CONCERNS IN A.I.D. PROGRAMS FOR LOCUST AND GRASSHOPPER CONTROL



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REVIEW OF ENVIRONMENTAL CONCERNS IN A.I.D. PROGRAMS FOR LOCUST AND GRASSHOPPER CONTROL IN AFRICA

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ACRONYMS AND ABBREVIATIONS

AELGA	African Emergency Locust/Grasshopper Assistance (A.I.D. Africa Bureau Project)
AGRHYMET	CILSS institute dedicated to study of agrometeorology and hydrology in the Sahel (Naimey, Niger)
A.I.D.	United States Agency for International Development
CIDA	Canadian International Development Agency
CITES	Convention on the International Trade of Endangered Species
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)
CPS	Crop Protection Service
DLCC	Desert Locust Control Committee, FAO
DLCO-EA	Desert Locust Control Organization for Eastern Africa (Addis Ababa, Ethiopia)
ECLO	Emergency Centre for Locust Operations (FAO)
EIS	Environmental impact statement, as required by NEPA
FAO	Food and Agriculture Organization of the United Nations
FEWS	Famine Early Warning System (A.I.D.)
GTZ	German Technical Assistance Agency
INSAH	Institut du Sahel (a body of CILSS)
IPM	Integrated Pest Management
IRLCO-CSA	International Red Locust Control Organization for Central and Southern Africa (Ndola, Zambia)
NEPA	National Environmental Policy Act (of the US)
NGO	Non-governmental organization
OCLALAV	French acronym for the Joint Locust and Bird Control Organization (Dakar, Senegal)
OECD	Organization for Economic Cooperation and Development
OTA	Office of Technology Assessment, US Congress
PEA	Programmatic Environmental Assessment (of the Locust/Grasshopper Control Program in Africa and Asia), cited as TAMS 1989
Sahel	Arid and Semi-Arid belt directly south of the Sahara Desert
Ramsar	International convention on Wetlands of international importance administered by an independent bureau hosted by the International Union for the Conservation of Nature and International Waterfowl and Wetland Bureau, World Wildlife Fund and the International Council for Bird Preservation
SEA	Supplemental Environmental Assessment
USG	U.S. Government

PREFACE

The U.S. Agency for International Development (A.I.D.), and a number of other donor nations, assisted African and Near Eastern countries in the control of locusts and grasshoppers during the 1986-89 outbreak. Much of the control effort involved the use of insecticides for immediate reductions in insect population. This document reports on the efforts A.I.D. has made and will make to apply environmental safeguards to pesticide use programs.

Chapter I summarizes the reasons for A.I.D. involvement in locust and grasshopper control in Africa. After some five years of operations in the most recent campaign, it is timely to review the progress of these programs and to set a course for the future.

Chapters II and III present information on major environmental and technical issues. This information comes from the Supplementary Environmental Assessments (SEAs) for Burkina Faso, Cameroon, Chad, Mali, Mauritania, Niger, Senegal and Sudan and a Programmatic Environmental Assessment (PEA) conducted earlier. A.I.D. Missions in Cape Verde, Gambia, Ghana, and Guinea-Bissau chose not to develop SEAs or to participate in control operations involving pesticides, but maintain an active interest in environmental issues. For example, the Mission in Cape Verde has been active in a program funded by AELGA, testing biological controls of locusts and grasshoppers, and until 1990 Guinea-Bissau had an active program in pest management support, including problems associated with obsolete pesticides. Relevant activities of the Asia Near East Bureau are not included, except when directly relevant to other African countries. Environmental Assessments have been conducted for Algeria, Morocco, Tunisia, and Pakistan. The report also discusses problems not addressed in the context of the PEA and SEAs and suggests the general directions of solutions to these problems.

Chapter IV provides a vision recommended for the major directions future A.I.D. programs might take with regard to grasshopper and locust management assistance. The discussion is intended to help the direction of future A.I.D. programs and the coordination with non-U.S. programs. In this regard, it will be useful to A.I.D. (particularly the Mission in each affected country) and in the outside community. Specifically, the report delineates the conditions under which A.I.D. should participate in pesticide procurement and use for locust and grasshopper control.

This report is dedicated to the many individuals who have worked to make a difference in Africa through efforts in locust and grasshopper control programs. We thank Doug Streett (USDA-ARS-RIL), George Cavin, Rafik Skaf and Jerome Roffey (FAO-AGPP) for their useful reviews and Gary Cunningham (USDA-APHIS-GHIPM), Patricia Matteson, and William Olkowski (BIRC) for comments. Millie Morton (Konan) provided valuable technical editing assistance. The French translation was reviewed by R. Skaf.

Opinions expressed herein are those of the contributors and do not necessarily reflect the position of the U.S. Government. For further information, or for copies of this publication, direct inquires to the U.S. Agency for International Development, Bureau for Africa. ARTS/FARA, Washington, D.C. 20523. This report is an outgrowth of the AELGA Project [Project #AFR-698-0517].

EXECUTIVE SUMMARY

This review summarizes A.I.D. environmental concerns and issues on pest management with special emphasis on locust and grasshopper control in Africa, describes technical and policy implications for control programs, and a vision for the future for such programs. A.I.D. has provided assistance to African nations to prevent crop damage by grasshoppers and locusts, and is currently designing approaches to this problem that should be both environmentally sound and functional in the context of sustainable agriculture and IPM.

In formulating an environmentally sound pest management framework, A.I.D. has applied the U.S. process of environmental regulation to issues in the African nations. Also, supplemental Environmental Assessments (SEA) were prepared for eight countries of sub-Saharan Africa--Burkina Faso, Cameroon, Chad, Mali, Mauritania, Senegal, Niger and Sudan. These documents are part of the effort related to the 1989 A.I.D. Programmatic Environmental Assessment (PEA) for Locust/Grasshopper control in Africa and Asia. In addition to assessing the environmental impact of pesticide-based management programs in each country, they contain country-specific recommendations and implementation steps for future A.I.D. supported programs. The PEA recommendations on environmental factors of pesticide use were analyzed in each SEA with regard to the special circumstances in the country discussed.

Through the preparation of these environmental assessments, A.I.D. can now assess specific areas where changes are needed. A major emphasis is to integrate pest managemer programs into overall programs promoting sustainable agriculture production. A.I.D. is interested in emphasizing activities that will have a long-term benefit to the host country infrastructure and will encourage the creation of organizations and facilities to strengthen environmentally sound pest control programs.

This review considers four issues: the reasons for U.S. involvement in pest control programs; major environmental concerns; major technical issues; and the implications and preferences for future actions.

Issue I. Reasons for U.S. involvement

1. Foreign governments, the USG, and entomologists worldwide identify locusts and grasshoppers as major threats to agricultural production and food self-sufficiency. Available historical scientific evidence indicates that high population levels of locusts and grasshoppers can have a negative effect on African food security. Several major species of locusts and grasshoppers threaten African crops, especially in massive, periodic upsurges. Outbreaks are usually associated with periods of rain following a drought. While locust outbreaks occur on an irregular basis, grasshoppers tend to be a chronic problem, especially in the more drought-prone regions.

2. The United States has information and resources to contribute to locust and grasshopper control. The U.S. has experience with Integrated Pest Management in the United States, and a history of involvement with agricultural issues in Africa. Part of the A.I.D. mandate is to help developing countries provide food security (as included in Strategic Objective Four of the Development Fund for Africa). Targeted are agricultural pests that threaten exports, agricultural commodities marketed domestically, and subsistence agriculture.

3. A.I.D. policy is to balance environmental issues with other issues of development. Although control methods in the past have been effective, heavy pesticide application has involved

environmental and human risks. Changes are needed in pest control operations in order to institutionalize an environmental awareness in both developing nations and donor countries. A.I.D. needs to stay involved in pest control programs in order to emphasize the need for environmental conservation.

Issue II. Major Environmental Concerns:

1. In the past, emergency locust control operations were deemed necessary to avoid widespread food shortages. But **emergency control efforts are neither economically efficient, nor environmentally sound.** A better approach is that of strategic and preventive control--detecting and treating locusts or grasshoppers while they are in small numbers in a confined area. With locusts, preventive control can be done in the recessional breeding areas. By using small amounts of well-targeted pesticides, preventive control is thought to be able to maintain locusts in recession indefinitely.

2. **Environmental protection is part of overall A.I.D. policy and must be reflected in all assistance programs where pesticide use is involved.** A.I.D. emphasis is on the development of sustainable agricultural systems and the use of Integrated Pest Management (IPM). Through IPM, African countries may eventually manage locust and grasshopper problems themselves, rather than being passive consumers of emergency aid programs.

3. **Information concerning the actual impact of pesticide use in Africa is scarce.** Further research and field testing is needed to understand the dynamics of locust populations and improve IPM techniques.

4. **The SEAs and the PEA identify the types of resources that might be at risk from pesticide programs, assess ecosystem vulnerability, and describe ways to minimize or eliminate impacts from control programs.** This review summarizes these issues and defines the present understanding of the major environmental issues in relevant pest management programs. Future A.I.D. program policy must be able to develop assistance projects in this field that will be environmentally sound, effective, and sustainable.

Issue III. Program Guidance Implications in Response to Environmental Concerns

Greater insights into the movements of desert and other locust species have made it possible to identify more precisely the recession areas for several species. USAID can use this information for preventive control.

Preventive control programs (also known as strategic control) require survey and monitoring techniques, including remote sensing, aerial reconnaissance, and terrestrial surveys. Also required are planning, using data from surveys and establishing pesticide banks and prepositioning pesticides in accessible areas. Economic thresholds must be established in order to determine whether pest damage warrants plant protection measures. These thresholds then must be assessed by A.I.D., considering the need for foreign assistance and the host countries' own resources.

Before considering the use of pesticides, alternatives should be assessed. If only pesticides are used, care must be taken to select only approved pesticides, and to minimize the impact of pesticides used, consistent with the aims of IPM. Possible A.I.D.-assisted grasshopper and locust management activities, are: 1) field

training of host country counterparts in IPM principles, proper pesticide safety, selection, and application methods; 2) pesticide management assistance, including proper labeling, handling, and disposal of obsolete pesticide stocks and empty containers; 3) human health programs designed to protect the public from exposure and to provide proper medical care in case of exposure; 4) review of potential environmental impacts from the management alternatives available; and 5) assistance with strengthening governmental control over pesticide use.

Research recommendations contained in the PEA discuss development of non-chemical or non-pesticidal control techniques, improvement of surveillance techniques, the use of remote sensing to assist in plague prediction, and improved pesticide and pesticide container disposal. In addition, the PEA suggests that future programs should incorporate or deal with: improved coordination between donors with respect to pesticide selection; assistance in improved pesticide storage and handling; and developing new training programs for IPM, biological control, pesticide use and sustainable agriculture, among others.

Issue IV. Environmental Aspects of Future Assistance Programs

Future assistance programs must recognize the importance of critical habitats and endangered areas and how these habitats can be impacted by pesticide use. Currently, A.I.D. requires that an inventory of all such areas must be done before beginning any project that includes pesticide activities. Assistance must include provisions to help the host country identify, understand, and protect ecologically vulnerable areas. Finally, the protection of these areas is closely tied to developing prevention and mitigation programs as opposed to control programs.

Future pest management assistance programs funded by A.I.D. should incorporate the following environmental and sustainable agriculture preferences in project development and implementation.

A. Minimizing Pesticide Use. Because of the inherent toxicity of pesticides to people, A.I.D. seeks to minimize their use in grasshopper/locust management assistance programs. Reductions in pesticide use will require an Integrated Pest Management approach, which will be emphasized in the context of sustainable agriculture.

B. Undertaking Preventive Control. A.I.D. should support a preventive control initiative similar to that now being developed by the Food and Agriculture Organization of the United Nations (FAO) for Desert Locusts. A.I.D. assumes that locusts and grasshoppers can be held in recession indefinitely by vigorous surveillance and prompt early season control. Although this approach is expensive during periods of recession, it avoids expensive emergency operations, and protects the environment from massive uses of pesticides applied under disaster conditions.

C. Improving Decision-Making. A.I.D. should emphasize research to develop intervention threshold criteria and should attempt to withstand political pressures for quick fixes. Actions taken in haste may not only be environmentally detrimental but also economically unjustifiable.

D. Developing Self-Reliance. To encourage the development of local self-reliance, A.I.D. should support institution-building in developing countries, including training in pesticide safety and use, and should encourage decentralization, such as by promoting village brigades, local control, and increased involvement by non-governmental organizations and the private sector. The U.S. has a vital set of political, economic and humanitarian interests in the developing countries of Africa (A.I.D., 1989). These interests are served by working toward improving the well-being of the populations of developing countries in ways that are self-sustaining and increase the self-reliance of the developing countries. In

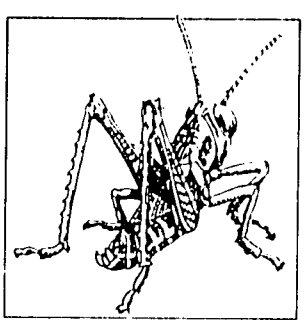
the context of locust control programs, this will mean building the capacity for pest control operations within the host governments.

E. Increasing Environmental Awareness. To provide some safety for Africa's unique mammals and birds, and increase awareness of the need for protection, National Parks, Wildlife Reserves and wetlands areas should not be part of A.I.D.-supported pesticide programs. These areas also serve as refuges for the development of natural diseases and parasites of locusts and grasshoppers. A.I.D. considers the environmental impact of projects prior to implementation. African ecosystems that are already under stress from drought and deforestation must not be strained further by the use of toxic compounds.

F. Reducing Uncertainty. A.I.D. should support improvements in the collection, maintenance and use of information. At the present time the lack of good information on insect-related crop damage hinders the development and implementation of pest management assistance programs. In treatment programs, records are often maintained minimally, with little institutional knowledge.

G. Developing Alternatives to Chemical Pesticides. A.I.D. should continue support for the development of methods of control that do not depend solely on synthetic chemicals pesticides. Within the IPM framework, non-chemical tools, including biological control methods, have the greatest potential for reducing reliance on synthetic chemical pesticides. Among these are cultural control methods including destruction of egg masses (not only is this method time consuming but it may not necessarily avoid chemical control in same areas, and it is needed twice due to variable dates of hatching), mechanical or manual trapping and crushing, (applicable at garden and near-field level, not at Sahel-level), capturing for human consumption, planting crops or varieties that are more resistant to damage (e.g., sorghum replacing millet), intercropping, anti-feedants, bio-pesticides, pheromones, kairomones, and synthetic growth regulators.

In summary, A.I.D. should aim to prevent outbreaks of locust and grasshoppers by emphasizing IPM approaches, focussing on prediction, minimizing pesticide use, and increasing the ability of affected nations to manage pest control themselves.



CHAPTER I

Basis for Involvement

CHAPTER 1
BASIS FOR INVOLVEMENT

1.0 Issue I. Reasons for U.S. Involvement with Locust and Grasshopper Control in Africa

1.1 Foreign Governments, the U.S. Government, and International Entomological Experts Identify Locusts and Grasshoppers as a Major Threat to Agricultural Production

Several major species of locust and grasshoppers have threatened Africa intermittently over the past century, indeed over two millennia. Damaging populations occur somewhere in the Sahel and Sub-Saharan Region each year, but massive upsurges over vast areas by principal species are episodic. These plagues are associated with periods of rains which promote new vegetation, and commonly follow periods of drought. Thus, the threat from locusts is of special concern because it comes at a time when reserves of food, finances and human endurance are at low ebb.

Desert locust (*Schistocerca gregaria*) populations exemplify episodic population changes. Locust experts agree that problems of general migration and geographic distribution exist (TAMS, 1989; Popov, 1988, 1990; U.S. Congress (OTA), 1990). Between outbreaks, the desert locust is found in the recession area, much smaller than the invasion area and breeds in wetter parts of the dry regions -- foothills of mountains, for example. Gregararisation occurs in these areas and successful breeding leads to upsurges and larger invasions culminating in plagues. Surveillance of these recession areas would allow predictions of when and where outbreaks are likely to originate.

Locust control experts believe that locusts can be held in recession indefinitely by systematic and vigorous surveillance and prompt preventive control (the basis for this assumption is discussed below in Section 2). This is the approach favored by FAO, the international organization with lead responsibility for locust research and control, under the rubric "strategic control." Though this approach seems expensive during periods of recession, the vigilance pays off in the long run by avoiding expensive emergency operations. The costs of strategic control, spread over a number of non-plague years, would be less than the costs of emergency control during plagues. In addition, the environment benefits by being protected from massive uses of pesticides applied under disaster conditions.

For these two reasons--economic efficiency and environmental quality--A.I.D. should continue to participate in locust/grasshopper control, through a program that is generally supportive of FAO's strategic control initiative. This document delineates the conditions under which A.I.D. should participate in pesticide procurement and use for locust or grasshopper control. Coordination with other donors occurs at the international and country level, where A.I.D. participates in planning meetings. For example, A.I.D. participated in the Desert Locust Control Committee and other technical consultations and planning meetings called or hosted by FAO as it has done for 40 years. In 1988, the U.S. government has used this forum to take a stand against the use of the persistent pesticide dieldrin. Currently, FAO meetings are the forum in which the difficult problem of disposal of obsolete or unwanted pesticides is being debated. A.I.D. has also worked with other donors, for example in the design of the international ecotoxicological testing program in Senegal (Evert 1990).

Donor coordination also occurs in individual countries. Most of the countries in which A.I.D. supports locust or grasshopper control have coordinating committees promotted by FAO that ensure donor awareness of other donors' activities. In most of these committees, unified campaign planning occurs; the needs are discussed and the various donors agree to provide support. As a major donor, A.I.D. can have significant influence on the decision to provide support and on the definition of the needs.

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's locust group focused only on desert locust problems, but its scope was broadened later to include other locusts and 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. Now it is one of 50 member countries. The Emergency Center for Locust Operations (ECLO), created in 1986 and housed in FAO's headquarters in Rome, bore operational responsibility within FAO. It assumed responsibility for raising donor funds and coordinating control activities during the recent upsurge through 1990, when it was disbanded, due to the recession status of desert locust. ECLO handled approximately $10 million in aid each year, in addition to coordinating some 150 projects funded by bilateral and multilateral donors, including FAO itself (FAO, 1990b). Responsibility for locusts and emergency operations at FAO reverts to the permanent office for migratory pests within the Agriculture and Plant Protection division, including a locust forecasting service.

FAO's activities include: supporting a centralized desert locust reporting and forecasting service in Rome; preparing and distributing the monthly FAO Desert Locust Bulletin, preparing special bulletins on other locusts and grasshoppers as needed; maintaining a semi-annual research and development register 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. FAO coordinates activities of the African regional locust and grasshopper control organizations and sponsors the FAO regional desert locust commissions in Africa and Asia, and donor coordination committees in each country receiving assistance.

Three semi-autonomous 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 Organization 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 (U.S. Congress (OTA), 1990; TAMS, 1989).

The organizational structure, mandate, membership, programs, and financial support of the African regional organizations continue to evolve. DLCO-EA is well established but is presently encountering acute financial difficulties. DCLO-EA was 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 (U.S. Congress (OTA), 1990).

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 (INSAH) of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) regarding a regional approach (Tropical Research and Development, 1989). A previous regional crop protection program of CILSS was terminated following withdrawal of A.I.D. funding. The CILSS-associated, meteorological organization AGRHYMET continues with A.I.D. funding to provide valuable weather information to member states. Also, the technology to produce vegetation index images (greenness maps) of the Sahel has been transferred to AGRHYMET.

Currently, IRLCO-CSA suffers from a lack of member states' payments, but donor assistance is being sought as a result of locust and grasshopper upsurges in the region (U.S. Congress (OTA), 1990). The International African Migratory Locust Organization was dissolved in 1986 (FAO, 1988a).

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) (FAO, 1989b). 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.

1.2 U.S. Experience with IPM and with African Agricultural Issues is Highly Relevant to Promoting Sustained Agricultural Production in Africa

U.S. experience includes over six decades of research and implementation of biological methods of grasshopper control in rangelands of the western USA, and a thorough understanding of the conceptual framework for IPM. A major emphasis is to integrate pest management programs into overall programs promoting sustainable agriculture production. The IPM principles of surveillance, early detection, and control actions, coupled with decision-making rules designed to minimize pesticide use can be implemented in Africa. A.I.D. is developing a database on IPM and is emphasizing activities that will have a long-term benefit to the host country infrastructure and will encourage the creation of organizations and facilities to strengthen continued development of environmentally sound pest control programs.

Developing countries of Africa have agricultural exports, agricultural commodities marketed domestically, and subsistence agriculture. All these types of agriculture are threatened by pests in Africa: pests that reduce productivity (such as weeds, locusts and crop diseases), pests that eat the produce in the field before harvest (such as birds), and pests that destroy the produce after harvest (such as grain-storage insects and molds). A primary assumption of A.I.D. assistance is that improving agricultural sustainability in Africa will require solutions to a variety of these threats to agricultural productivity.

Underlying A.I.D.'s approach to these threats to agricultural productivity are 1) that pesticides are a necessary component of any successful program at the present time and 2) that pesticides have the potential for environmental detriment. The toxicity to non-target organisms of various pesticides used in locust and grasshopper control varies widely and each pesticide must be considered in view of its selectivity, efficacy and toxicity (Table 1). As a result, risk can be assumed to be reduced by any decreased reliance on pesticides.

Protection of the environment is part of the cost of doing business. Even though the value of Africa's unique bird life is difficult to determine economically, and the linkage between loss of aquatic invertebrates and fish productivity is poorly quantified, A.I.D. is committed to the principle that protecting these resources is part of the cost of doing business. The SEA for Sudan even sets aside a portion of the cost of a control program, to be earmarked for activities specifically supportive of environmental quality.

1.3 A.I.D. Policy is to Act as a Voice of Environmental Conservation with a Goal to Balance Environmental Issues with Other Issues of Development

1.3.1 A.I.D. Concerns

At present, A.I.D. is taking a major role in advocating restraint in the use of chemicals, in defining and defending environmentally sensitive areas and in exploring the possibilities for environmentally sound disposal of obsolete pesticides. For example, A.I.D. recently sponsored a workshop on obsolete pesticide disposal and is currently

TABLE 1: TOXICITY OF VARIOUS PESTICIDES TO NON-TARGET ORGANISMS

Chemical	Persistence	Bioaccumulation	Birds	Mammals	Fish	Aquatic Invertebrates
Carabaryl	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

NOTE:

[a] Fenitrothion is moderately toxic to fish, Foster L. Mayer, Jr. and Mark R. Ellersieck, Manual of Acute Toxicity: Interpretation and Data Base for 410 Chemicals and 66 Species and Freshwater Fish, Resource Publication 160 (Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, 1986), pp. 224-30.

[b] Based on log P.

MODIFIED FROM: 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.

negotiating with an international agrochemical firm for the return of obsolete pesticides to the country of origin for disposal. In the past, A.I.D. provided the leadership for the cessation of dieldrin use.

Individual A.I.D. missions may choose a level of active participation based upon both the degree of infestation and on the capabilities of the National Crop Protection services. Some Missions choose to refrain from participation in control operations if the locust/grasshopper problems in the country are minor, other donors, particularly those with strong current environmental interests, are taking an active role. A.I.D. is then able to focus resources in other areas. However, non-participation results in a loss of ability to influence the extent to which the environment is taken into account in locust control programs.

Similarly, if A.I.D. withdrew from locust and grasshopper control, it would lose its ability to provide the leadership in improving the protection of the environment. A.I.D. recognizes that ecosystems in Africa are under increasing stress originating from natural and human influences, and is firmly committed to avoiding actions which add to those stresses. Use of pesticides, of course, is among the actions which could add to stresses. The pesticides commonly used in locust control, if applied incorrectly, have direct effects on aquatic invertebrates and other non-target organisms. They also can have either direct or indirect effects on birds. For these reasons the areas in Africa that have been designated as protected (National Parks, Wildlife Reserves) and all wetlands areas, should be free of A.I.D. supported pesticides. This will be true regardless of how well or how poorly those resources are protected from other stresses.

This "designation of protection" from A.I.D. supported pesticides should not only provide some safety for Africa's unique mammals and birds, it also will increase the awareness of the need for protection in those countries. Such increased awareness is badly needed. Among other benefits, having protected areas set aside will provide refuges for the development of natural diseases and parasites of locusts and grasshoppers. Some experts have speculated that the natural cycles of locust plagues are related to the increase and decline of natural diseases and parasites (in addition to the availability of food). Though this speculation is unsupported by data, it is a reasonable, logical and testable hypothesis. Prudence argues that until this hypothesis is tested, refuges for the protection of natural diseases and parasites are a wise and inexpensive investment. A.I.D. should insist on the designation and protection of areas free of pesticide use in any country.

One of the difficulties encountered in the design of remedial or preventive policies is the problem of evaluating the cost of environmental degradation and the benefits of preventive or remedial actions. The new applications of benefit-cost analysis to environmental economics, based on welfare economics, bristle with ethical and value issues. For instance, what is the nature and extent of the obligations of present or future generations, or of man's obligation to non-human creatures, and to non-living objects? In order to compete for the attention of government and commercial decision-makers in today's world, policies regarding biological diversity and natural resources have taken four main approaches that have been used to determine the value of these resources. These are:

- consumptive use value (assessing the value of nature's products that are consumed directly without passing through a market);
- productive use value (value of products produced commercially);
- non-consumptive use, option or existence value (indirect value of ecosystem functions such as watershed protection, production of soil, and keeping options open for the future); and
- social, ethical and cultural value (value of the resource recognized in religion, art, literature and other social mechanisms).

Even estimating financial costs of depletion and degradation is difficult because these costs are not reflected in the marketplace. National accounts in most developing countries do not account for the depreciation of man-made assets, nor for the decrease in value of natural resources. In practice, there is little quantitative data in developing countries on the effect of environmental degradation. Methodologies are, however, now being developed to address the issue of the valuation of natural resources. Bishop (1969) estimated the cost of soil erosion in Mali, and it is expected that these methodologies will be useful with respect to issues in that country. From data available on physical erosion, researchers estimated the costs and benefits of natural resources management in Burkina Faso (1990) in order to appreciate the economic dimension of the renewable natural resource issue. They concluded that benefits from improved management of renewable natural resources are very high but that the costs are also very high, presenting the country with difficult macro-economic choices.

It has sometimes been argued that environmental controls and regulations retard growth and country development. The application of this view to Africa has not been closely studied, but the experience of six OECD countries may be similar. In the 1970s, the growth of environmental regulations and expenditure (regulations on the emission of noxious wastes, installation of pollution control devices, technological changes in production process) coincided with poor economic performance in the OECD countries. Whether environmental regulations (which affect costs, output, employment, productivity, prices and hence the balance of trade) have constrained economic performance is an empirical question which the OECD study attempts to answer through macro-economic modelling for six countries. The main conclusion which emerges is that the macro-economic effects of environmental policies are relatively small; the effects of increased pollution control measure on the growth of output are indeterminate (from - 1.0 percent for the U.S. to + 1.5 percent for Norway). The effects on inflation appear slightly unfavorable with an average annual increase of 0.3 to 0.5 percent.

Conversely, employment is stimulated, with an implicit worsening of productivity growth. It also appears that the initial impact, through increases in output, is more favorable than the long-term effect, through increases in prices. This conclusion suggests that pollution control measures were not a major cause of the slowdown in productivity growth of the OECD's countries in the 1970s, and therefore would not hamper expansion in the 1980s. This economic impact is evaluated solely in terms of macro-economic effects, and did not attempt to quantify the beneficial effect of pollution control measures on the quality of life (OECD, 1985).

The cost of environmental protection has been considered overzealous by some with regard to the use of dieldrin in the control programs. The use of pesticides with lower persistence (which replaced dieldrin) probably necessitates more frequent applications, which increases cost. The justification of this increased cost has been that dieldrin, by its persistence, presents an unacceptable risk from bioaccumulation and food-chain transfer, which in turn can translate into increased risk to human health and environmental organisms (FAO, 1988c). This increased cost provides a measure of the expense of being environmentally aware. If, for instance, it is determined that field operations without dieldrin will cost an additional $2 million[1], then this is the cost of preventing the environmental risks associated with its use. These costs and costs associated with other aspects of environmental protection (for instance, preservation of biological diversity, see Section 3) should be part of a conscious decision--and a case made that they are worthwhile.

Assessing costs may expose an inefficient basis or unacceptably expensive approach. Perhaps alternatives, such as the often mentioned goal of prevention rather than control programs, need to be more actively pursued. Another important alternative is non-pesticidal approaches to control (see below) or hooking into longer-term programs related to total crop protection measures. For instance, it has been estimated that improving grain storage to decrease spoilage by as little as 2 percent might be more cost effective than all of the locust prevention programs.

[1] This number is only for purposes of illustration and its relation to actual costs is unknown.

1.3.2 U.S. Regulations

A.I.D. environmental regulations have evolved in the context of domestic environmental issues. This section will briefly describe the A.I.D. environmental regulations that required preparation of the Programmatic Environmental Assessment and Supplemental Environment Assessments for the locust/grasshopper programs.

22 CRF Part 216, A.I.D. Environmental Procedures

Regulation 216 (also known as Reg. 16) specifies procedures by which environmental consequences of A.I.D.-financed activities are to be identified and considered by A.I.D. prior to project implementation. Appropriate environmental safeguards are to be adopted. The procedures were developed to ensure that environmental factors were integrated into the A.I.D. decision-making process and are consistent with Executive Order 12114 of 1979 and the U.S. National Environmental Policy Act of 1970.

Foreign Assistance Act, Section 117, Environment and Natural Resources

Section 117 of the Foreign Assistance Act addresses the problem of degradation of natural resources and of hydrological deterioration. The amendment authorizes the President to furnish assistance to develop and strengthen the benefits of conservation activities which may be largely external to the country. Preservation of the capacity of developing countries to protect and manage their environmental and natural resources is vital. For instance, special genetic resources used for pharmaceutical countries may benefit international companies and consumers. The amendment requires that an Environmental Assessment or impact statement be prepared when major Federal actions are undertaken.

Foreign Assistance Act, Section 118, Tropical Forests

In passing Section 118 in 1986, Congress recognized the importance of forests and tree cover to developing countries. Properly managed forests provide a sustained flow of resources to developed and developing countries alike. Of particular concern is the accelerating alteration, destruction or loss of tropical forests. The amendment requires that the recommendation of the United States Inter-Agency Task Force on Tropical Forests is to be given a priority in formulating programs and carrying out policies with respect to developing countries.

Foreign Assistance Act, Section 119, Biological Diversity

Section 119 requires that each country's development strategy statement or other country plan proposed by A.I.D. is to include an analysis of the actions necessary to conserve biological diversity, and the extent to which actions proposed for support by the Agency meet the identified needs. A.I.D. is required to cooperate with appropriate international organizations both governmental and non-governmental; to look to the World Conservation Strategy as an overall guide; and to perform other activities to conserve biological diversity. In particular, A.I.D. must deny direct or indirect assistance for actions which denigrate national parks or similar areas, or introduce exotic plants, animals or other biological agents.

Policy Determination (PD-6)

Policy Determination (PD-6) regarding Environmental and Natural Resource Aspects of Development Assistance (April 1983) declares that A.I.D. policy is to help less developed countries build institutional and scientific capacity regarding critical environmental and resource problems; establish resource management programs; ensure environmental and long-term sustainability of projects; and promote environmentally sound development. The PEA and SEAs satisfy PD-6 by addressing the environmental sustainability and soundness of improved access, with particular attention to induced secondary development that may occur as a result. The confirming

recommendations regarding resource management programs, including a list of mitigative measures, are intended to reduce or avoid adverse impacts.

Pest Management Guidelines

In 1991, A.I.D. issued a new set of Pest Management Guidelines that more fully define the conditions under which A.I.D. will participate in pest management activities in developing countries. These new guidelines describe in general terms the technology and approaches to be used for pest control, and the environmental protection procedures to be followed. The primary approach for pest control is integrated pest management, and the environmental procedures are those of Regulation 216. The environmental assessment of the locust/grasshopper control program, as described in the SEAs and in this document, is consistent with the Pest Management Guidelines.

1.3.3 International Regulations

In 1987, FAO incorporated a "Prior Informed Consent" (PIC) provision into the International Code of Conduct on the Distribution and Use of Pesticides (adopted by FAO in 1985, FAO 1986b). The code set out recommendations for the safe use and storage of pesticides, and the disposal of aged materials. A working definition of PIC (FAO 1988b) is "PIC, in the context of the code, means the international shipment of a pesticide that is banned or severely restricted, in order to protect human health or the environment, should not proceed without the explicit agreement of the designated national authority in the importing country having been provided with all relevant information." The U.S. government endorses this code.

The U.S. government is also a party to other international conventions on natural resources, including Ramsar and CITES and the 1979 convention on the Conservation of Migratory Species of Wild Animals. The Ramsar convention of Wetlands of International Importance (signed 1971) is agreed to by 54 countries including the U.S. It is administered by an independent bureau hosted by IUCN (International Union for the Conservation of Nature) and IWRP (International Waterfall and Wetland Bureau), WWF (World Wildlife Fund) and ICBP (International Council for Bird Preservation). The 1975 Convention on International Trade in Endangered Species (CITES) was developed by IUCN and UNEP. By 1988 the CITES treaty had been signed by 96 countries; 675 species could not be traded commercially and 27,000 species were restricted.

CHAPTER 2
MAJOR ENVIRONMENTAL CONCERNS

2.0 *Issue II. What are Environmental Concerns with Regard to A.I.D.-Funded Locust and Grasshopper Control Programs in Africa?*

2.1 *Concern 1.1: Controlling Locusts and Grasshoppers Through Emergency Operations is Inefficient. Preventive Control is Preferable.*

Although past emergency locust control operations were deemed necessary to avoid widespread food shortages, emergency control efforts are neither economically efficient, nor environmentally sound. By the time an emergency has developed, locusts or grasshoppers have reached high population numbers and large amounts of pesticides must be used to achieve control. In addition to killing the target pest, such quantities of a pesticide will also impact the area ecosystem. A far better approach is that of strategic and preventive control, a method which involves detecting and treating locusts or grasshoppers while they are in small numbers in a confined area. With locusts, this can be done in the recession breeding and gregarization areas. By using small amounts of well-targeted pesticides, preventive control is thought to be able to maintain locusts in recession indefinitely.

The preferred approach--preventive control--involves detecting and treating populations of locusts or grasshoppers before they reach the outbreak stage or leave their recession breeding areas. While the combined recession and invasion areas for the various migratory locusts species cover virtually all of Africa, the recession areas for desert locust are much smaller (Figure 1). Preventive control requires knowing what constitutes being "on the verge of outbreak" (i.e., a measure of the population that can lead to an outbreak), and having a surveillance system sufficient to detect locusts at those numbers. The currently favored combination of techniques to give a comprehensive and efficient surveillance system includes remote sensing, aerial reconnaissance and terrestrial survey. Each of these techniques requires careful data collection, interpretation and reporting. A.I.D. supports this full range of surveillance tools, including training to improve the quality of data collection and analysis.

Though these techniques seem expensive during periods of recession, the vigilance pays off in the long run by avoiding expensive emergencies and by protecting the environment from massive uses of pesticides applied under disaster conditions. A.I.D. should support FAO's preventative control policy for West and North-West Africa (FAO, 1991).

2.2 *Concern 1.2: The Seriousness of Locust and Grasshopper Problems Needs Better Definition*

Locust swarms are highly visible, and areas where they feed are often devastated. Local crop losses of 100 percent are possible and losses of 20 percent in a given district are not unusual. In the face of these facts the threat of locust plague can be terrifying. However, country-wide losses are seldom more than a few percent and seldom equal the losses from other causes. Because of the visibility of locusts, the local political pressure to act is often excessive. Thus, a careful comparison of alternatives is seldom conducted during a plague.

As a world leader in agricultural productivity, the U.S. chooses to work on problems that have the greatest potential for return on each dollar of development aid spent. In the context of Africa, cost efficiency may argue for improving soil conservation and fertility, controlling other pests and diseases, or improving storage facilities, rather than controlling locusts. However, cost efficiency is difficult to calculate because the base of information is poor. In the face of such uncertainty, A.I.D. chooses programmatic approaches that have the potential for transference. The locust/grasshopper program, for example, places some emphasis on institution-building within

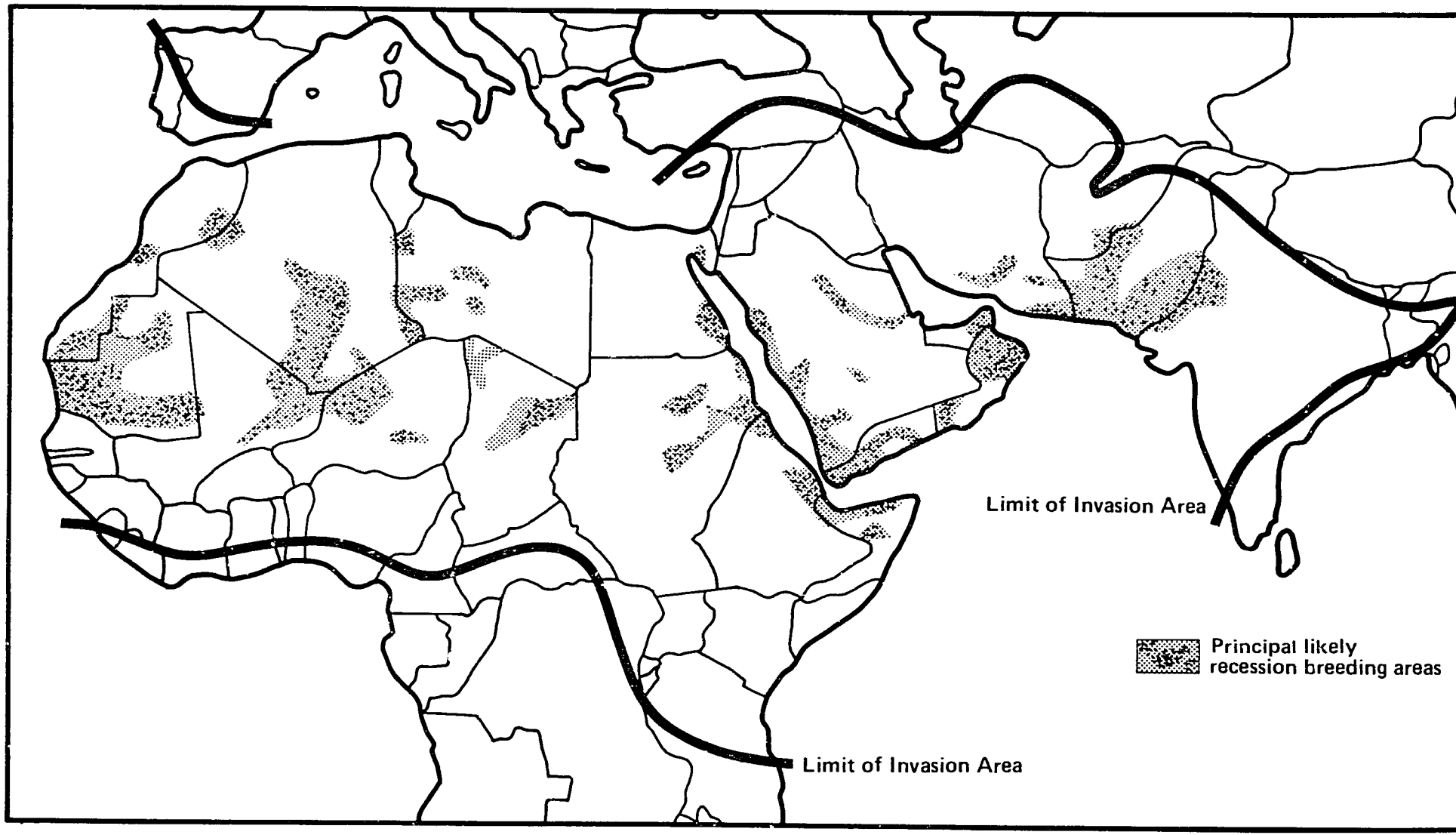


Figure 1. Principal areas of breeding and gregarization of desert locust hoppers and adults during recession periods (from 1920 to 1976), in relation to the limit of the invasion area of desert locust swarms during plagues (1941 to 1968). Adapted from Pedgley 1981.

the host countries in order to increase their self-reliance in pest control activities, regardless of what pests are predominant in any given year. Thus, the locust control program is not merely preventing the damage caused by locusts, but also developing the capability to control pests responsible for other losses. Institutionalizing this capability within Crop Protection Services of individual countries will increase those countries' self-reliance. Despite this broader perspective, A.I.D. also expects locust control programs to be justified economically as if they were stand-alone programs. To this end, considerable emphasis is being placed on economic thresholds and the decision process for triggering treatment efforts.

When locust populations appear to be high, or loss of crops is perceived as severe, political pressures to intervene are a major consideration. Political pressures do not always favor controls and prevention programs. A.I.D. involvement can serve as a voice for moderation in opposing overreaction during plagues and underreaction during recession.

Since data on crop loss is poor and economic justification is marginal at best, the prudent approach is to withstand political pressures for quick fixes to the maximum extent possible. Actions taken in haste due to the high visibility of a large locust swarm may not only be environmentally detrimental but also economically unjustifiable. A.I.D. should employ decision rules that err on the side of restraint.

A major debate exists on whether locusts and grasshoppers are a major cause of crop loss and whether the costs for the control efforts are justified. The U.S. Congress (U.S. Congress (OTA), 1990) has focused the debate in six areas: 1) the impact of locusts/grasshoppers on food production; 2) the importance of locusts and grasshoppers in relation to other pests; 3) the extent to which locusts/grasshoppers cause famine; 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 surges; and 6) the extent to which the benefits of control, in terms of crops saved, exceed the cost of control.

The direct benefit of control campaigns can be assessed by estimating the value of crops threatened or saved. Indirect benefits such as institutional development of national crop protection services also exist but are largely unquantifiable and are thus often not included in cost/benefit calculations.

The value of the crops threatened depends on the crops, with values only easily established for cash crops such as sorghum and millet. However, in many locust invasion areas, crops are largely grown for subsistence and values can not easily be assigned, especially since the micro-level economic and socioeconomic research has not been done. Experts agree that the value of crops saved is more relevant than the value of crops lost (TAMS, 1989). However, this is no easier to determine.

The PEA (TAMS, 1989) summarizes the best available estimates for the costs of grasshopper and locust damage and emphasizes the wide margin of error for the estimates. For example, potential damage from desert locusts in Morocco was estimated at $125 to 250 million in 1988, based on the assumption that damage would be comparable to that seen in 1954 and 1955, when a "freak event" trapped locusts in the narrow Sous Valley, a fertile agricultural area (U.S. Congress (OTA), 1990). Economic thresholds are examined in Section 3.5.2.

When the direct costs and benefits are examined, the monetary costs of the 1986-89 control program may not yield a favorable net return in terms of the amount and value of the crops saved (U.S. Congress (OTA), 1990). The cost-effectiveness of the locust and grasshopper control programs has also not been demonstrated, largely because of the scarcity of data (see Section 2.4). However, assuming the direct cost benefits of the program cannot be demonstrated, the value of indirect benefits, oversight in environmental concerns, participation in multi-country operations, and opportunity to contribute other knowledge would still appear to justify the program.

2.3 *Concern 2: Environmental Protection is Part of the Overall A.I.D. Development Policy*

Applying the U.S. process for environmental assessment in Africa is difficult but not impossible. Past locust/grasshopper programs have taught A.I.D. many important lessons with respect to environmental assessments and the application of the U.S. processes to overseas situations. And, in the process of doing environmental assessments, we learn about major substantive issues related to these assessments (see Chapter 3) and issues related to the legal framework for environmental assessment in Africa.

2.3.1 Environmental Regulatory Processes in an African Context

Of the eight sub-Saharan African countries where SEAs have been completed (see 2.3.2), none has general environmental policy laws or regulations that are similar to those required in the U.S. National Environmental Policy Act (NEPA). This Act requires that all proposed programs of the U.S. be evaluated as to the potential for environmental impacts. The A.I.D. regulations discussed above (Section 1.3.2) are derived from this environmental legislation and are concerned with development programs that may have a potential for environmental impact. Since the African nations have no corresponding regulations, A.I.D. is not required to perform environmental assessments in connection with proposed projects or policies. Any existing environmental legislation and regulations are generally outdated and not-well enforced. All the countries have established some form of national parks or wildlife reserves. However, communities may live within the parks, carrying out everyday activities such as farming and fishing. Further, the boundaries of the parks are not generally well-defined and the commitment to the maintenance and protection (e.g., policing) of these parks is minimal. Finally, the movements of peoples induced by prolonged droughts, civil and international wars, and the process of desertification, have brought significant human impacts to the parks.

None of the eight countries has the complex of laws and regulations covering the use of pesticides and toxic substances which are characteristic of developed nations. Where laws and regulations do exist, the country generally lacks the mechanisms and resources for enforcement.

The countries have increased sensitivity to the need for regulations and changes are underway. For example, Mali recently passed a toxic waste law, and draft legislation has been proposed on pesticide importation, use and distribution. Sudan is currently in the process of revising its Pesticides Act of 1974 and expects the revision to be in force by 1991 . Burkina Faso and Mali have regulations that support registration and tracking of pesticide use--although those regulations do not require environmental reviews of potential effects from the use of the pesticides. Niger has similar regulations pending. Through growing awareness and education, regulations are being developed but the debate often involves a view of the environment that varies from that found in the United States, with different concepts of boundaries, ownership and conservation.

The dearth of appropriate and enforced regulations concerning pesticides, particularly in Africa, means that there is little effective regulation of locust control efforts by the host country. Thus, the use of A.I.D. Regulation 16 is likely to be a controlling element for the near future.

2.3.2 A.I.D. Environmental Process with Respect to Locusts and Grasshoppers

The rapid increase in population of locusts and grasshoppers in 1986, after a long period of recession, led to a declaration of an emergency situation by A.I.D. Mission directors. A.I.D./Washington concurred and waived the use of Regulation 16 for the emergency control activities. A.I.D., urged on by interested non-governmental organizations, then began to prepare a programmatic environmental assessment (PEA) for this program in 1987. The report, a year in preparation, was then reviewed and approved for use in the program. Based on this report, A.I.D. developed a guidance document (A.I.D., 1989c) for missions to prepare supplemental environmental

assessments (SEAs), which were intended to present a country specific approach to issues identified in the PEA. Concurrently A.I.D. designated environmental officers in each mission(s) for oversight and advice in this and other environmental matters.

SEAs, prepared with assistance from environmental experts from A.I.D./W, are in the process of being finalized by each Mission. Reviews by A.I.D./AFR/TR Washington of SEAs for the eight countries covered by the Africa Bureau (Mauritania, Senegal, Chad, Sudan, Mali, Cameroon, Niger and Burkina Faso) revealed that many concerns have not yet been addressed. None of the SEAs were sufficiently specific to environmental concerns in each country to address many operational field issues, and allow complete assurance that all environmental matters will be addressed. Rather the SEA read as a list of concerns that should be considered but do not provide a set of steps that must be made before pesticides are used in locust campaigns. Since the SEAs fulfill legal requirements and are the primary tools that will be used by A.I.D. to ensure that proper environmental controls are being maintained, each Mission was encouraged to follow a checklist of activities prior to locust and grasshopper operations. This checklist is intended to ensure that the most important environmental issues are addressed (see Section 2.5).

Major issues related to protecting human health and non-target organisms are commonly covered in environmental assessment in the U.S. In Africa, poorer sources of information make assessment more uncertain and the implementation of recommendations more difficult. Despite these constraints, the PEA determined the potential for impacts and what needed to be done to minimize such impacts. The PEA listed 38 recommendations for future locust/grasshopper control programs. The SEAs add country specificity to the recommendations in the PEA, in some cases adding new recommendations. The SEA for Sudan, for example, contains more than 90 individual recommendations. In addition, the Africa Emergency Locust/Grasshopper Assistance Program (AELGA) had conducted a mid-term evaluation that listed a number of changes in direction that would be appropriate, and the Office of Technology Assessment (OTA) reviewed locust and grasshopper control programs and issued a report "A Plague of Locusts," with a number of suggestions (U.S. Congress 1990). A.I.D. takes these recommendations seriously and will be considering them in future locust or grasshopper control programs.

2.4 Concern 3.1: Available Information Needs to be Better Utilized

Information is needed for surveillance for the prediction of outbreaks, to formulate and implement economic thresholds, to understand crop loss, to carry-out good treatment programs, to protect ecological resources, and to understand locust and grasshopper population dynamics. Even if the information base was extensive, resources available to mitigate damage would be difficult to obtain. Despite the difficulties, A.I.D. will emphasize the need to improve the collection, maintenance and use of information in all these areas.

2.5 Concern 3.2: Checklist of Needed Information

As a result of preparation of the PEA and the SEA's, a checklist for environmental issues related to Locust and, Grasshopper Assistance Programs was developed. It provides a useful guide to several of the important data sets. These are:

1. Has the Mission complied with all applicable environmental regulations and procedures (see Section 1.3.2 especially), including pesticides, Reg 16? These regulations specify that an analysis of the impact of all activities be completed before activities are started. This checklist and the materials in the SEA are designed to help officers fulfill this requirement.

2. Is the mission using pesticides on the approved A.I.D. list (Table 4)? Are other pesticides being used from other donors? (Normally A.I.D. will not participate in programs involving non-

approved pesticides). Are pesticides being used only under approved conditions, such as avoiding certain types of habitats? For instance, are bird nesting areas being avoided when using fenitrothion and propoxur, and aquatic resources avoided with diazinon, lambda-cyhalothrin, tralomethrin and cypermethrin.

3. Is the program planned to be as effective as possible with the least amount of pesticide use possible? Have you considered alternate methods to using pesticides been considered? Have activities been coordinated with other local groups, including FAO? Has the analysis considered

   a. stage of crop development,
   b. age/development stage of insects, and
   c. economic threshold? Have greenness maps and other remote sensing aids been utilized in making your decisions?

4. Has equipment been tested and calibrated? Have personnel been properly trained in use of equipment and concerns in 5?

5. In what areas of the country will operations occur?

   a. Are personnel aware of all possible endangered species that may be impacted? Have measures been taken to avoid or minimize impacts on them and their habitats?

   b. Are there any National Parks, protected areas or critical habitats within the operation area? How are impacts being mitigated for any operations that must be conducted? (Normally activities are not allowed in these areas. When locusts are found in these restricted areas only controlled spraying, such as the use of back pack sprayers, are allowed.). Are buffer zones of at least 2.5 km being maintained?

   c. Are all operations near surface aquatic resources maintaining a buffer of 1000 feet?

   d. Are villages and populated areas being exposed? Are people warned of operations (using radio and other means) or evacuated? Are all operations at least 2.5 km from these resources?

   e. If answers and information is incomplete, what plans are being made to gather information before operations begin? Have diligent efforts to obtain additional data been made? Is information being collected and stored to assist in future operations?

   f. How has information been communicated to operations personnel (pilots, pesticide personnel/supervisors, etc.)?

   g. Are spraying areas properly delineated by use of flags or other suitable means?

   h. Are aerial spray operations minimizing wind drift by spraying at appropriate time in day (such as early morning)?

   i. How was information obtained about the location of species to be treated? Is it reliable? Has it been verified?

6. Are approved aircraft being used in operations? Are certified or qualified pilots being used for these activities? The smallest practical aircraft should be used in order to minimize overspraying and to ensure more precision in placement of pesticides with respect to resources in 5.

7. Are appropriate (e.g. high exposure) pesticide personnel being tested for excessive exposure through cholinesterase tests? Have health personnel in the operations area been alerted to pesticide activities and have they been trained in the recognition and treatment of symptoms?

8. Are pesticides being handled to avoid spilling into natural resources? Are cleaning operations for equipment using pesticides also protecting these resources. In sandy areas, or near areas of large slopes these operations can endanger rivers, streams, and groundwater; these are sources of drinking water and habitats for aquatic organisms.

9. Are pesticide containers disposed of properly (Overholt and Castleton 1990)? Are drums crushed and perforated to avoid use for drinking water and food storage?

10. Are stocks of pesticides being stored properly to avoid spillage or leakage? Have Missions been notified of stocks that are in need of disposal? Has the best disposal method from perspective of efficacy, practicality, cost, health and environmental protection been selected? (Balance the danger of keeping pesticides around against potential of impacts from disposal techniques.)

2.6 Concern 4: What are the Potential Environmental Impacts?

2.6.1 Environmental Criteria

Evaluation and monitoring of the impact of pesticides on vulnerable, fragile, or critical resources is essential. Consideration needs to be given to the protection of biodiversity, the avoidance of ecological changes, and the potential effect on natural enemies, and any impact that could reduce the benefits of pesticide use. Environmental criteria need to consider the potential impact resources and pesticide selectivity with respect to flora and fauna.

2.6.2 Non-Target Impacts

Few studies have examined the impacts of pesticides on human health and the natural environment. The most extensive study of pesticide impacts was a study in the Sudan in 1987 (Dynamac, 1988) on the efficiency and environmental impacts of six commonly used pesticides. The methodologies of the Sudan study have been extensively criticized. Recently, a pilot study was completed by the FAO in Senegal (Evert, 1990) and this is being followed upon with a three-year ecotoxicology research project (LOCUSTOX).

The Senegal study, one of the most comprehensive to date, attempted to measure the impact of commonly used locust/ grasshopper insecticides on non-target organisms. Terrestrial anthropods and aquatic anaimals (particularly crustaceans) were significantly affected, and effects on locusts were observed in some cases. Matteson (1991) argues that these sets of tests are also not representative of natural conditions because they inadequately account for effects of experimental plots that can easily be repopulated from untreated areas.

In Africa, environmental awareness is still largely centered on potentially adverse effects on human populations, and to a lesser extent, on their livestock. Concern for the well-being of other life forms, particularly if they have no readily visible economic importance, is not part of the African cultural heritage. Education of crop protection

service personnel, government officials, and the general public, will change this awareness, but changes will come slowly.

None of the countries report systematic monitoring of the impacts of locust/grasshopper spraying on the biota in treated areas. Except in Senegal, national crop protection services have neither the trained personnel nor the infrastructure necessary for the preparation, preservation, and analysis of samples. Sudan has extensive capabilities, but the facilities are unable to function for lack of basic chemicals and materials, while the lack of dependable electric service affects use of instruments.

2.6.3 Vulnerability of Resources and Resources at Risk

Environmental assessments must focus on the potential for damage in African ecosystems. These are discussed below. The PEA discussed the vulnerability of several types of habitats (Table 2). The cost of protecting these resources was discussed in Section 1.3.

TABLE 2: VULNERABILITY OF AREAS IN AFRICA

Habitat/Area	Concern/Comment
Desert, grasslands and areas in bloom	Pollinators active, increased game, animal, and bird life. Chemicals semi-arid are applied during brief moist period when all biota are active and reproducing. And all semi-arid zones fragile, simple ecosystems with relatively few species. Areas already under stress due to erosion, desertification, deforestation and overgrazing.
Temporary lakes and marshes	Annual fish species, congregates of birds.
Seasonal (rainfed) cropland	Pollinators on bird populations.
Rivers/permanent lakes and swamp	Pollinators, important on irrigated crops, major fisheries, bird populations. Crops are planted up to edge of receding flood waters, so no buffers possible if crops to be protected. Specific sites on Blue Nile, Niger at Senegal Rivers.
Rice paddies	Birds and fish.
Permanent inland swamp (Niger Inland Delta and Lake Chad wetlands)	Birds and fish.
Wildlife reserves and protected areas	Prime grasshopper habitats. Conflict of interest between endangered species, protected areas and locust and grasshopper control.
Human exposure	Nomads/herds in grazing areas; people eat locusts; shallow wells in desert and semi-arid oases.

SOURCES: TAMS Consultants, Inc., March 1989, Locust and Grasshopper Control in Africa/Asia.

2.6.3.1 Vegetation and Wildlife

The major vegetation types of Africa can be described as: forest, with its altitude-related and edaphic trees such as montane, swamp, mangrove, and bamboo forests; thicket; mixed forest-grassland formations, such as woodlands, wooded savannas, tree and shrub savannas, and steppes; grasslands, such as grass savannas and steppes; desert and semi-desert vegetation; and nilotic vegetation.

Throughout Africa, the main vegetation types are subject to change. In West Africa, for example, forest land in the shifting cultivation cycle will, after cultivation, successively change from shrub and bushland fallow to woodland, to secondary forest and back to forest proper in the course of 20 years or so. Where fallow periods become shorter woody vegetation will not re-establish itself. Clearing land for wood products or new agriculture will also bring change. Looking to the future, it is clear that deforestation will continue and that forest and woodland will be converted to crop production and other uses. At present, the annual rate of deforestation is some 3.7 million ha per year.

The distribution of vegetation in Africa is closely correlated with climatic conditions and modified by topography and soil. Most of the vegetation has been disturbed, often severely, by man. It does, however, provide food, fodder, fuel and building materials, protect the land from erosion, and help restore fertility. The use and conservation of vegetation is, therefore, an essential ingredient of any strategy to increase agricultural production in Africa.

Many of Africa's wildlife species are familiar either because they are spectacular or because they have been so often photographed and popularized. It is important to realize, however, that Africa's various habitats support many more less spectacular species of wildlife that comprise carefully balanced communities. For example, the Serengeti plains of Tanzania are known for the variety of wildlife they support (many species in large, concentrated numbers). Prides of 20 to 30 lions are not uncommon. Thousands upon thousands of gazelles roam the plains, as do millions of wildebeests. However, the biomass of all these mammals does not equal that of the largely unseen insects supported by the plains.

Different habitats are characterized by different wildlife communities. In the vast savannas and grasslands across Africa, the enormous variety of wildlife is apparent (unlike the wildlife characteristics of forests). But the grassland areas are likely to diminish more as a result of degradation than as a result of conversion to cropland.

Natural vegetation provides the habitat for Africa's varied and important animal resources. The importance of the wildlife resources includes, but is not limited to:

1. Wildlife (small mammals, birds,and invertebrate, and larger species) contributes significantly to the protein portion of some local diets: as much as 66 percent in rural areas of Botswana, 70 percent in Liberia and 75 percent in Ghana.

2. Compared to domestic livestock, wild mammals are more efficient converters of natural vegetation to meat, are better adapted ecologically with greater disease resistance, and require less management. Attention is therefore being given to methods of exploiting them more effectively. Small rodent breeding for food has potential in this context.

3. National park and wildlife based tourism is an important source of foreign exchange revenue in some countries, and has potential in many others.

4. Animals are a unique part of the African environment and play a significant role in ecological processes. Without the fauna found in all habitats, these processes are interrupted, leading to myriad detrimental spin-offs for ecosystems, including the disruption of biological diversity.

5. Birds that migrate through and utilize African resources are particularly important and they can be affected by pesticides since locust invasion areas are in some cases also located in the important European/African flyways (Figures 2 and 3).

Wildlife is at risk precisely because it is wild and cannot be kept out of sprayed areas. Particularly at risk are insectivorous and predatory birds and also migratory birds. The impact of insects on avian fauna was the object of a study in the Nara/Dilly zone of Mali (Dynamac, 1987). A.I.D. and FAO conducted complementary studies in Senegal (Keith and Mullie, 1990; Everts et al, 1990) to evaluate the effect on birds and invertebrate of insecticide treatments applied during the locust campaign. Little data exists on other life forms, so that it is impossible to predict which, if any, may be at risk as the result of pesticide applications in any treated area. The dangers locust/grasshopper control activities (using A.I.D. approved pesticides) may impose on any of the rarer species, are likely to be far less severe than the continued loss of habitat to expansion of cultivation, deforestation, overgrazing, and desertification.

2.6.3.2 Aquatic Resources

The hydrology of the African continent is dominated by four major river basins: the Nile, the Zaire, the Niger and the Zambezi. Most of the African rivers remain relatively unmodified and are associated with extensive wetlands in the form of floodplains, swamps and lakes, all of which are considered critical habitats. In general, Africa has less available surface water per unit area, higher evaporation and (a consequence of the first two factors) less runoff into the sea per unit area than other major regions of the world.

The African continent has a wide variety of water bodies including lakes, rivers, reservoirs, floodplains, lagoons, estuaries, mangroves and small natural and artificial water bodies which support fisheries, plus a growing number of aquaculture activities. These waters total more than 450,000 square kilometers or about 2 percent of the total continental area (TAMS, 1989).

The limnological characteristics of African waters vary enormously and, thus, their productivities, but almost all except the high alkaline lakes of the Rift Valley provide the basis for commercial or subsistence fisheries. Fisheries are economically and socially very important in Africa as a source of employment and income, food or foreign exchange in different proportions depending on the kind of fishery. For some half dozen countries fish represents over 10 percent of the total protein supply from all sources while in some 12 or so countries consumption of fish is equal to or exceeds that of meat. The importance of fish in the dietary pattern of many African countries is enhanced by the fact that it helps to correct a basic protein/caloric imbalance caused by heavy dependence on grains or starchy roots. Where fish play a prominent part in national dietary patterns, inland fisheries provide a significant proportion of total supplies. Lakes and reservoirs account for about half the freshwater fish production, and the construction of new reservoirs adds to this each year.

2.6.3.3 Animal Resources

Beneficial Arthropods

Beneficial arthropods can be classified as those which are principally of economic importance, and those which are of ecological significance. Bees, for example, fall into the first class because of their use in honey production and in the pollination of commercial plant species (e.g., fruit trees). Examples of ecologically significant

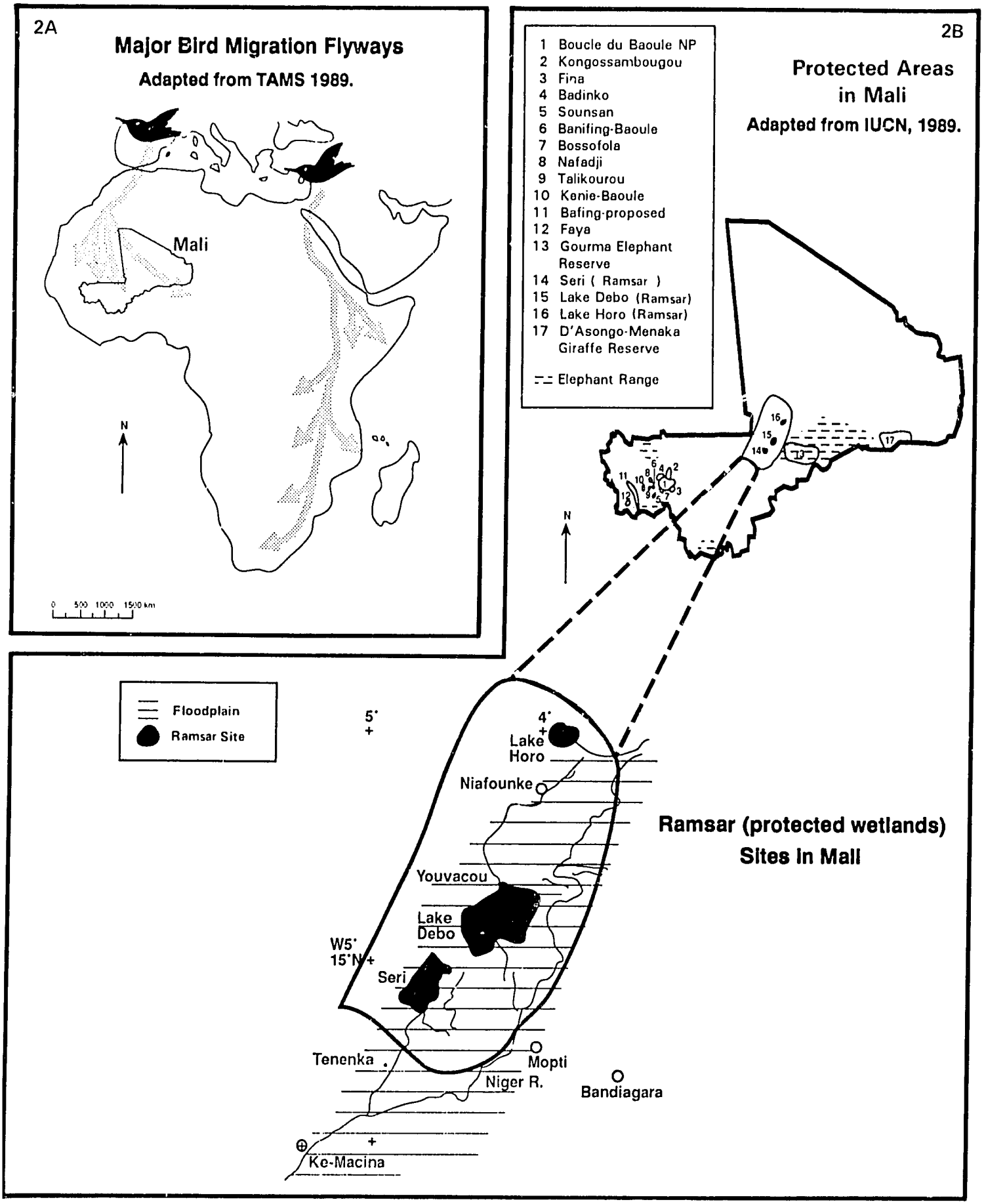
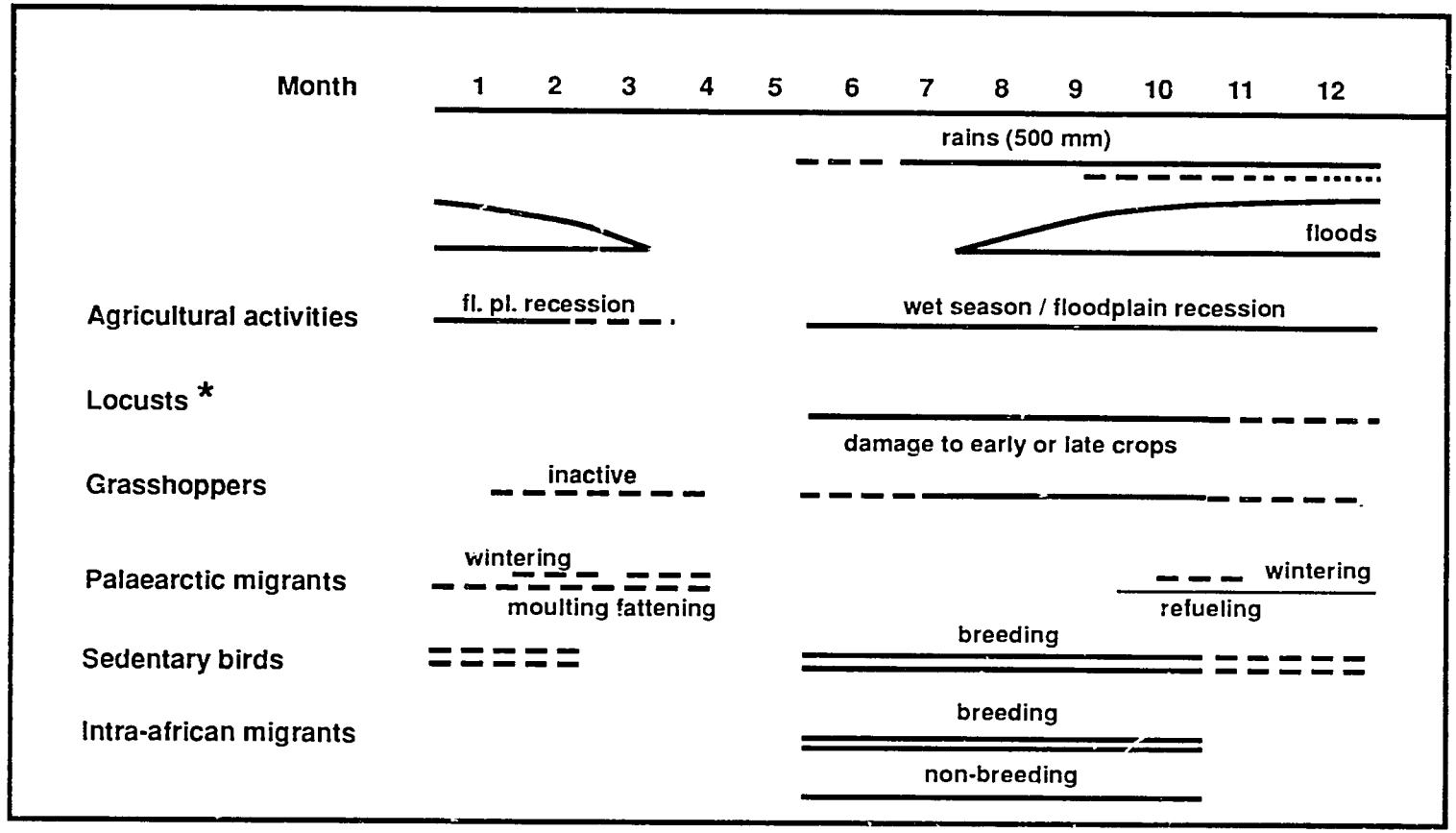


Figure 2. Examples of biological resources potentially at risk from pesticide use: case of Mali.



* Not present in cropped areas during recession periods

Figure 3. Life-cycle characteristics of West African birds and locusts/ grasshoppers in relation to seasonal land use activities and rainfall.

organisms could include insects which are important in the food webs of local ecosystems, or which are involved in the maintenance of soil quality.

For grasshoppers, further consideration needs to be given to the impacts of pesticides at different phases of control. Early season control focuses on concentrated grasshopper populations and, if effective, should dramatically decrease the amount of pesticide needed in later phases. The second phase occurs later in the season when populations are distributed over wider areas. The third phase occurs when the populations are even more widely distributed. Treatments made after that time are sometimes made in an attempt to decrease the number of females before egg laying occurs. Results of recent field work in Senegal suggest that late season treatments could potentially increase the number of grasshoppers the following years by decreasing the mortality inflicted by natural enemies (Everts, 1990). Such matters need study because they are central to the IPM approach.

Livestock and pastures

Little evidence exists concerning problems in livestock caused by pesticides. Mitigative measures (listed below) may reduce any threat to the important livestock economy of the countries. More important protection will be afforded by the implementation of the public notification practices. Since nomadic herders may graze livestock in pesticide-treated rangelands, it is important to find ways to ensure that livestock are kept out of the treated areas during post-treatment periods.

2.6.4 Protected and Critical Habitats

Protected areas are those which, by national policy, decree, or practice, have been identified as being of singular importance to a nation (Figure 4). These would include, but not be limited to, national parks and wildlife reserves for the preservation of threatened and endangered species. Critical habitats include terrestrial and aquatic (freshwater and saltwater) areas. Humans encroach on most protected and critical habitats in African countries often to a significant degree. African countries place certain restrictions on human activities (such as hunting), but do not prohibit human habitation (including agriculture) in the pattern of national parks in developed nations. The cumulative effects of desertification, drought, refugees and wars have severe negative impacts on protected areas, which are often protected only in name. Avoiding further negative impacts is imperative. In locust/grasshopper activities, A.I.D. Missions should make the avoidance of further negative impacts a prime operational goal, and, through coordinating activities with other donors, seek to educate and assist country governmental agencies in meeting environmental protection goals.

Aquatic resources are particularly critical because they often incorporate large areas of space, including watersheds. Lakes, rivers and their tributaries are obvious parts of these, but another type of aquatic environment is the wetland, which is often the site favored by migrating birds. Locust/grasshopper populations can breed in or near such habitats. Terrestrial habitats include vast areas of grasslands, which are often devoid of human population, except for nomadic peoples and their livestock.

2.6.4.1 Terrestrial Areas

In order to preserve national parks, game reserves, and similar areas, special care must be taken to protect them from pesticide-induced impacts. But when game reserves are invaded by locusts, compromises must be developed, such as allowing the use of dust bags and ground applications to maximize precision of pesticide application.

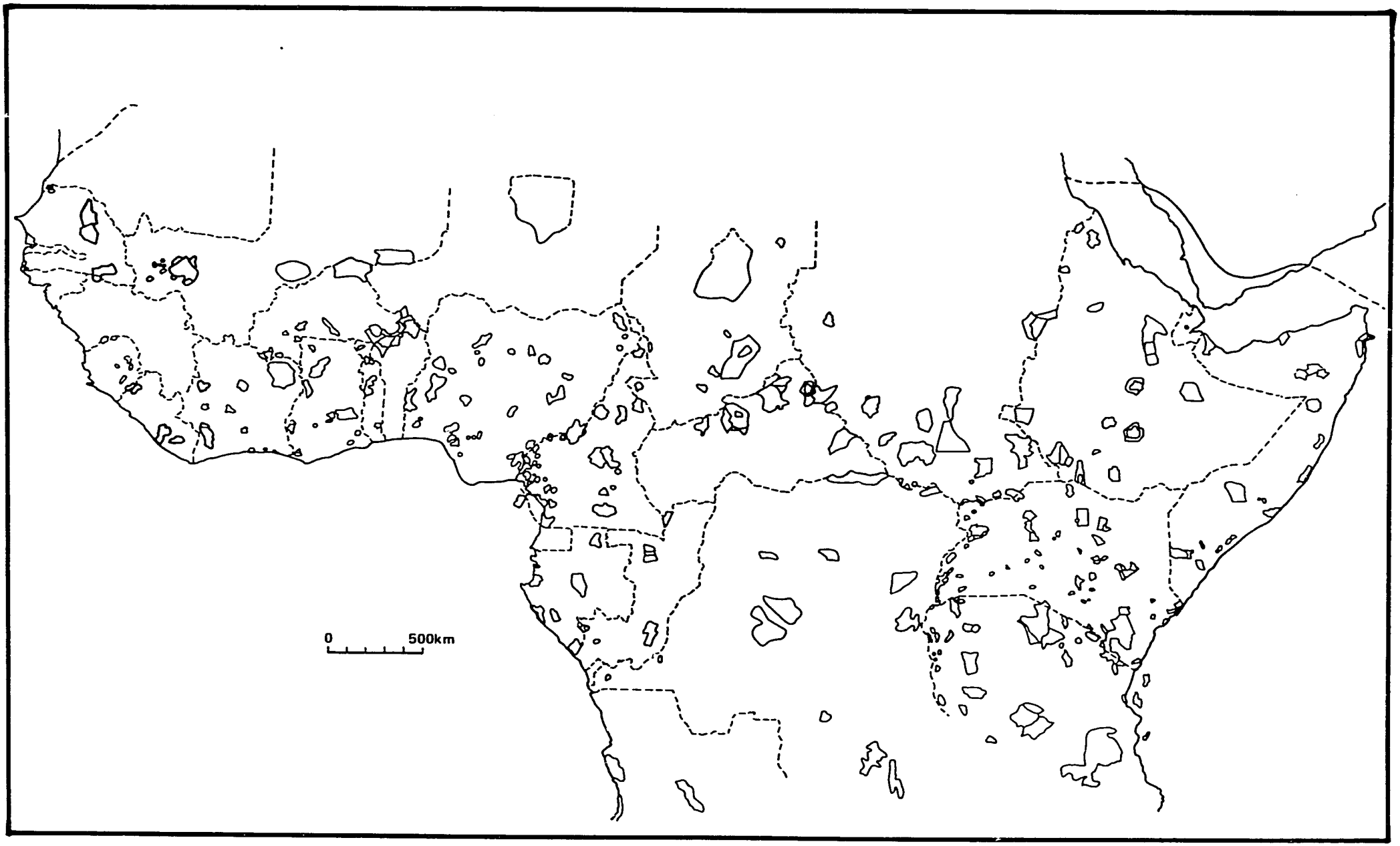


Figure 4. Distribution of key protected areas in northern sub-Saharan Africa. Adapted from IUCN, 1986.

2.6.4.2 Permanent Surface Waters

The Lake Chad Basin is an example of an extensive, multi-national, permanent body of water. Farming takes place in areas along its many tributaries; fishing occurs in the streams and the lake itself. The variety of terrain also incudes wetlands which are another special habitat, especially for birds. Without concerted action by all the countries comprising the basin (Chad, Niger, Nigeria, Cameroon), preventive actions might be for nought, and fragile areas might be degraded or destroyed, with significant impact to the biota and to humans who are dependent on the lake's productivity. A mechanism for regional response and agreement on practices in all forms of pesticide use (not just locust/grasshopper control) exists in the Lake Chad Conventional Basin Commission (LCBC). This Commission, assisted by the respective A.I.D. missions and other donors, could develop and implement meaningful guidelines and practices of the national CPSs, and could mount a large educational effort for the general population.

A second example is the Sudanese system between the two main branches of the Nile River (the Blue Nile and the White Nile). Dams along the rivers and on the main Nile River have interfered with natural replenishment mechanisms for aquatic flora, thus magnifying any negative impact. Thus, great care must be taken in the selection and use of pesticides near these rivers. Unfortunately, greater amounts of pesticides and herbicides are used for agriculture than are used for locust/grasshopper control. Large amounts are used in the irrigated cotton and mechanized farming areas, which ultimately reach the Nile. In addition, pesticides are used for Quelea bird control. Until recently, extensive growths of water hyacinths were controlled by herbicides. The introduction of three species of weevils seems to have been very effective and the use of herbicides has dropped sharply (this is an example of control by a non-chemical method that is desired for the locust/grasshopper program).

A final example of a critical habitat is the Inland Delta of the Niger River (Mali). As it straddles the midpoint between the Sahelian and the Sudanian zones, the geomorphology of the inland delta has made the region biologically and geographically unique. In fact, without upsetting the climatic rhythms of its environment, the inland delta has, so to speak, "created an original atmospheric ambiance." The Niger delta, located in the heart of the Sahel, allows the presence of species normally found farther to the south. Birds gather by the millions in the flood zone. Migrating species arrive to spend the winter and leave again in March for the Northern Hemisphere. The flood zone is also a gathering place for many Ethiopian species which reproduce between two migrations. The protection and management of these birds is one of the goals of the project called the "Environmental Conservation of the Inland Delta of Niger."

2.6.4.3 Temporary Water Bodies

Although devoid of water for much of the year, the wadis and tributary drainage lines in the desert are vital for animals, birds, and arthropods, as they are the sole local sources of shelter and sustenance for many of these creatures. Pools which remain in the larger "river" beds are utilized by numerous seed-eating birds and other wildlife. Because many of these habitats occur in the desert, and are a sole source of water, they are very important. Thus, even in desert environments, it is especially important not to contaminate these "temporary" water bodies with pesticides.

CHAPTER 3
MAJOR TECHNICAL ISSUES AFFECTING PROGRAM GUIDANCE

3.0 Issue III. Program Guidance Implications in Response to Environmental Concerns

The application of technical information in locust/grasshopper programs will improve the extent to which assistance programs are environmentally sound. Previous assistance from the A.I.D. and other donor nations involved the extensive use of insecticides that have potential environmental detriment, especially to birds and to aquatic invertebrates. This chapter outlines the efforts A.I.D. has made in determining the extent to which insecticides are harmful, and in designing methods of preventing or mitigating detriment in future control programs. Each A.I.D. mission now has an environmental officer to assist in program development. The A.I.D. Locust/Grasshopper Management Operations Guidebook (A.I.D. 1989d) provides detailed implementation guidance.

3.1 Biology and Movements of Locusts/Grasshoppers

Of the major species of locusts and grasshoppers shown in Table 3, the desert locust has the greatest potential for agricultural destruction (although there is considerable debate about the actual extent of destruction, see below). They have the potential to invade 29 million square kilometers, an area that has 65 countries with 10 percent of the world's population.

Over the past 30 years, research has provided numerous insights into locust movements and distribution (Popov, 1988, 1991; Steedman, 1988). Within north/northwest Africa, desert locust swarms generally move east-to-west to the north of the inter-tropical convergence zone (see below) and west-to-east to the south of it. In general, summer breeding areas are located in the countries of the Sahel and the predominant movements of swarms produced in these areas are east-to-west, south-to-north and southwest-to-northeast. Winter breeding areas are located in the countries of the Maghreb. Predominant swarm movements are north-to-south and northwest-to-southeast. Spring breeding occurs in the Maghreb countries followed by swarm movements mainly north-to-south and from northwest towards southeast. Winter breeding may take place in Mauritania, Mali, Algeria and Niger. Breeding areas of eastern Africa (northern Somalia, Red Sea coast of Ethiopia and Sudan are important due to the large number of generations produced annually.)

In recession periods the desert locust lives and breeds in the solitary phase in areas of the Sahara that experience an annual rainfall of less than 250 millimeters. Sparse populations exist on vegetation in the wadis and mountain runoff areas. Important habitats that have these characteristics are found in the northeast of Chad (Tibesti-Ennedi), at the convergence of the frontiers of Mali, Algeria and Niger (Hoggar, Adrar des Iphoras, Air), in the south and west of Mauritania, in the extreme west of the Algerian Sahara at its frontier with Morocco and in the Hamada el Hamra in Libya.

Areas where gregarisation occurs are more difficult to define. In general, they coincide with the zone already mentioned (the Adrar des Iphoras, the Air) together with the Tamesna (Niger and Mali) and the Adrar Soutouf (Morocco). These zones are particularly suited to swarm generation because they are situated between summer breeding areas in the south and winter/spring breeding areas in the north. They also contain areas in which moisture conditions are particularly favorable to the locusts due to mountain relief and runoff. These patterns were seen in 1986-89.

TABLE 3: MAJOR SPECIES OF LOCUSTS AND AGGREGATING GRASSHOPPERS IN AFRICA AND THE MIDDLE EAST

Locusts	
Desert Locust *Schistocerca gregaria*	This species is potentially the most dangerous of the locus pests because of the ability of its swarms to fly rapidly across great distances. The pest has two to five generations per year.
Africa 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, Madagascar, 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, Western and Southern Africa and Madagascar. 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 with xerothermic mediterranean climate extending from Morocco in the west, the Near East, Soviet Central Asia, Iran and Afganistan. 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 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 from U.S. Congress (OTA) (1990), TAMS (1989) and Uvarov 1977.

3.2 Relevance to Locust/Grasshopper Programs of African Physical/Climatic Environment

The combined recession and invasion areas of the nine major species of locusts and grasshoppers cover virtually all of Africa. Africa experiences northern hemispheric equatorial and southern hemispheric climatic regions. These climatic regions, combined with the topography of Africa, have produced environments ranging from deserts to humid tropical rain forests and areas affected by frost and snow highlands (FAO, 1986a).

Locust and grasshopper movements are affected by several important geographical features of Africa. In the northwest, the Atlas Mountains of Morocco and the Piedmont Atlas of Algeria act as barriers to the northwest spread of the desert locust during the plague periods. If cool weather prevails, locusts will remain to the south of the mountains. In the northeast, the mountains of the northern section of Somalia force locusts west to the border of Ethiopia, and south to the Ogaden desert and on to Kenya. Alternately, locusts may move east to the horn of Africa (east point of Somalia) and to southern Somalia and Kenya.

The northern highlands of Ethiopia (Tigra and Eritrea) slow the movements of locusts to the breeding areas of the Red Sea coast. The Saudi Arabian escarpment bordering Tihama and Hejaz prevents locust movement to the interior of Saudi Arabia during the winter months. The same is also true for the mountains of Yemen and Hadramaunt. The northern mountains of Iran prevent movement of locusts to the Caspian region of northern Iran and southern Russia during the winter months. Surprisingly, the Sahara, Arabian, and Pakistan and Rogistan deserts of India appear not to impede locust movement. Some researchers argue that locusts can only cross to Yemen and the east when the inter-tropical convergence is present, and the wind direction with which locusts are associated allows them to cross the Red Sea to Yemen (personal communication with Cavin, 1987).

3.3 Relevance of Weather

Rainfall patterns determine hatching, location of breeding and aggregation of locusts and grasshoppers (TAMS, 1989). In the Sahel, rains normally begin in May and extend to November with first rains occurring in the south and then progressing north. The most northerly regions have sparse rainfall, often under 50 millimeters. In sub-Saharan zones, the Middle East, Morocco and south Asia, rainfall reaches 50-200 millimeters, provide breeding zones for the desert locust. Other species (particularly *O. senegalensis*) need rainfall of 200-1000 millimeters and can breed in West African (Gambia to southern Mauritania). Short rains (an extra seasonal rain period in March) and storms (particularly cyclones) off the Indian Ocean are part of more complex weather patterns in East Africa. In these complex moisture zones, breeding patterns are more complicated. Finally, some species of grasshoppers such as the variegated grasshopper, prefer to breed in drier periods of the year.

The Tibesti, Air, Adrar, des Iforas and Ahaggar mountains of Algeria are habitually wet areas because of fronts forming in the inter-tropical convergence zone. These areas are breeding areas for locusts and important habitats for many species.

The inter-tropical convergence exhibits a periodic movement from the south (near the Equator) in the winter to the north (Sahara regions), creating weather fronts and rain, and setting up important wind patterns. In general, the winds flow into areas of low pressure associated with the inter-tropical convergence. To the north of the front, winds flow southwest, while to the south they flow northwest. Along the front, winds generally flow east/west and facilitate movement and orientation of the locusts and grasshoppers.

Locust populations are keyed to rainfall and temperature, increasing in wet years and decreasing in times of drought.

3.4 Survey and Monitoring

The preferred approach--strategic control--involves detecting and treating populations of locusts or grasshoppers in their recession breeding areas when they are on the verge of outbreak. This approach requires knowledge of what constitutes being "on the verge of outbreak," a surveillance system sufficient to detect locusts and grasshoppers at those numbers, and the ability to effectively mount a control program at specified locations. Currently, several techniques give a comprehensive and efficient surveillance system: remote sensing, aerial reconnaissance and terrestrial survey. Each of these techniques (described below) requires careful data collection, interpretation and reporting. A.I.D. supports a full range of surveillance tools, including training to improve the quality of data collection and analysis.

Remote sensing consists of satellite photography converted into "greenness maps" that show which areas have vegetation growing into a potential food source for locusts or grasshoppers. The technology for producing these greenness maps has recently been transferred from the EROS center in South Dakota to the AGRHYMET center in Niamey, Niger (Tappan, et al. 1991). Having an African source of these maps will ensure that they are timely and inexpensive to the users across the Sahel.

Aerial reconnaissance often links remote sensing and terrestrial survey. Though the greenness maps serve to focus the subsequent survey efforts on the locations most likely to have developing populations of locusts or grasshoppers, the size of the countries of Africa and the small number of trained individuals make it necessary that each individual cover large areas. That makes the use of aircraft in surveys mandatory in many cases to gain access to the site if not to observe it in its full breadth.

Ground Survey is the backbone of surveillance. No technology developed at the present will substitute for identification of species by a trained individual on the ground at the site of the suspected infestation. That individual must be able to accurately quantify and distinguish species and growth stages (e.g., identifying different species when they are in the nymph stage). In addition, a major component of a good surveillance system includes egg pod surveys, determining the number of eggs in a breeding field as a means of predicting the potential for next-season outbreaks.

3.5 Control Strategies: Campaign Plan

3.5.1 Pretreatment Planning

3.5.1.1 General

A.I.D. prefers that locust and grasshopper programs be planned in advance. One of the consistent, generic requirements of the SEAs is to establish plans that define the details of implementation prior to A.I.D. involvement. Campaign plans provide protection for human health and the environment and give details of resource and staff allocation, assigning responsibility for specific aspects of implementation.

3.5.1.2 Forecasting

Pretreatment planning includes use of the best technology available for predicting the probability of locust or grasshopper problems, the use of greenness maps for allocating field survey resources, and the use of egg pod surveys for next-season prediction applies mainly to *Oedaleus*. Treatment decisions are based on field surveys conducted by trained personnel who can distinguish various species of locusts and grasshoppers (with different potential for damage), and accurately estimate the real potential for losses in crop productivity.

3.5.1.3 Pesticide Banks

Pesticide banks consist of agreements to share a common pool of chemicals among separate potential users, either by bilateral or multilateral agreements among the users themselves, or by centralizing the "bank" in an organization, such as FAO or European Economic Community, that has a broad area of responsibility. Pesticide banks help prevent the build up of excess pesticides within African countries, by ensuring that a number of potential users have an adequate centralized supply which can be provided on short notice to areas where a need has been determined and verified.

3.5.1.4 Repositioning Pesticides

Repositioning pesticides involves moving pesticides to field locations where they are likely to be needed prior to the expected use date. Repositioning is essential to timely control--particularly under the poor road conditions in some parts of Africa during the rainy season (when locust and grasshopper control normally occurs). Disadvantages include increased potential for human exposure, for misuse or loss of pesticide due to poor storage conditions, and for obsolescence of pesticide due to dispersed stockpiling.

3.5.1.5 Conclusions About Pretreatment Planning

A.I.D. strongly advocates pretreatment planning and preparedness, especially the monitoring of populations of problem species to predict future needs. With locusts currently in recession, neither pesticide banks nor repositioning are as urgently needed as they would be in the midst of an emergency. Pesticide banks and repositioning are less relevant to grasshopper control programs.

A.I.D. supports both pesticide banks and repositioning and is establishing an AELGA pesticide bank. However, A.I.D. believes that both pesticide banks and repositioning should be used with caution. Pesticide supplies must be carefully controlled to prevent obsolescence and should be dispersed only to locations having proper storage facilities to ensure protection from weather and to safeguard human health and the environment.

3.5.2 Economic Threshold

Economic thresholds are defined as levels of pest damage which warrant the use of plant protection measures. Two terms frequently used in considering control measures are defined by Stern et al. (1959) as follows: (1) economic-injury level is the lowest population density which can cause economic damages and (2) economic threshold is the amount of injury which will justify the cost of artificial control measures. In economic terms, the economic injury level is the break-even point at which the value for an increment of loss in yield quantity or quality is equal to the cost of a control method that successfully eliminates pest damage and yield loss (Frisbie et al. 1989).

The ability to determine an economic threshold of an insect or other pest on a crop is dependent on distinguishing the different infestation levels and the degree to which each level influences the harvested crop (Stern 1973). According to Talpaz and Frisbie (1975) a threshold is a dynamic measure which may vary with infestation level, value of yield, cost of control, time of assessment, etc.

One approach to this assessment was made by Coop (1989 and 1991), in which he related grasshopper density to crop loss in Mali. Five grasshopper and two blister beetle pests of millet were caged over millet panicles using nylon sleeves to determine relative damage rates on the milky grain stages for grasshoppers and the flowering stages for blister beetles. Highest damage rates from the grasshopper occurred during the early and middle milky grain stages; lower damage rates occurred during other stages. By contrast, blister beetles caused almost no

damage to flowering millet. Based on this assessment, a formula and sample calculations for estimating economic injury levels were developed.

Whether a single economic threshold can be applied to peasant farms is questionable. As noted by Farrington (1977), the assessment of pest densities and of the pest/host plant relationship as well as costs of control are likely to vary widely among farms and from season to season. In peasant agriculture, farms are usually very small and crops frequently occur at different stages of growth within a small area. Therefore, the use of a single threshold and pest count is likely to result in an "over investment in pest control for some farmers, under-investment for others, and the economically optimal investment for perhaps only a minority." There is a pressing need for a flexible system of threshold such as is used in the control of cotton bollworms in Malawi (Beeden 1972). Here a scouting aid "pegboard" consisting of a wooden block with three rows of holes is used. A peg is moved along each row to record the number of plants samples as well as egg counters for two main bollworm pests. The decision to spray is taken as soon as the egg count crosses the appropriate threshold line marked on the board. The device assists the farmers in making their own insecticide recommendation, and involves no reading or writing (Kumar 1984).

With locusts and grasshoppers, economic analysis focuses around two issues. First, what are the alternative actions that might be taken instead of providing locust\grasshopper control programs? Second, such programs are provided, at what point will the amount of resources available for investment in efficient and effective locust\grasshopper control programs satisfy the desire for these services?

Clearly, the entire program deserves detailed examination. In a comprehensive but preliminary report by FEWS (1987) the best available data were examined. About 3.8 million hectares were treated in the Sahel at a cost of $41.7 million dollars. The value of the production in the affected area was valued at $78 million, but $31.9 million of this production was lost anyway. Thus an investment of $41.7 million saved production worth $46.1 million, a benefit/cost ratio of 1.1 to 1. In the detailed mid-term program review by A.I.D. (TR&D 1989), these conclusions were examined more closely. A change of one FEWS assumption--that the pests if left unchecked would have placed additional production at risk--by ten percent of the amount actually treated, would change the benefit/cost ratio to 1.3 to 1.

With respect to alternative investment options to the present program, A.I.D. (1987a) and TAMS (1989) have identified a continuum of activities that vary from no control action to more intensive activities. No control is unacceptable because of U.S. public desire to assist in emergency situations in Africa and expert opinion on pest management that the locust/grasshopper populations would grow rapidly to uncontrollable levels if left untreated. Other programs such as food aid programs for the individual farmer affected or funneling funds through the FAO or another agency have been rejected unworked and as inefficient. Limiting treatments to infested crop areas only has been rejected by the U.S. and European community as an inadequate implementation concept. USAID has also been reluctant to undertake programs that support institutional development of national plant protection services because of past lack of success and the host countries' inability to afford associated recurrent costs.

It has been postulated that in economic terms, no isolated or independent locust/grasshopper "marketplace" exists (FEWS 1987). Instead there is a market in which a potpourri of African host country requirements for foreign economic development assistance compete for priority, with political, social and development implications. Thus, they reason that responding to a phantom "locust/grasshopper" market place will lead to their control as "unfunded realities" and that the vicious cycle of locust/grasshopper plagues will not be addressed.

The economic analysis for decision making is impeded by lack of appropriate information, inability to properly evaluate the value of components to the program, and lack of a solid macro-economic framework for the overall analysis.

3.5.3 A.I.D.'s Intervention Threshold

When USAID participates in locust or grasshopper control programs, it is expected to be under one of the following levels of infestation:

Level 0: The expectation of the grasshopper/locust control program is that a gradually strengthened crop protection service in the host country will have increasing ability to maintain locusts in recession and grasshoppers at low levels of infestation without outside intervention. As level 0, only non-chemical technical assistance will be provided. USAID is committed to continuing to provide assistance at this level.

Level 1: Level 1 assumes an infested crop area of 50,000 to 300,000 ha, where the threat is "localized" and swarms are not likely to impinge on neighboring nations. Level 1 infestation usually occurs in agricultural and inhabited areas, where local personnel can be mobilized for a ground campaign.

Level 2: Level 2 assumes a more severe infestation of about 500,000 ha in crop and pasture land, and the potential of desert locusts to gregorize and then swarm to other countries. At Level 2, USAID participates with a target of contributing no more than 15 percent of the funds needed.

Level 3: Level 3 assumes a widespread infestation of much more than 500,000 ha and a greatly increased threat to other countries. At this level, the resources of host countries and donors are likely to be exceeded, and significant crop losses are expected. Funding levels would be expected to exceed $10 million.

In making specific decisions about needed level of support, A.I.D. should exercise restraint. recognizing that over the last few years, the use of pesticides has been gradually increasing.

3.6 Pesticide Selection

3.6.1 Rationale (Country-Specific A.I.D.)

Pesticides used in foreign aid programs are selected on the basis of their efficacy, cost, stability, availability, toxicity to workers and compatibility with environmental concerns (TAMS, 1989). A.I.D. has conducted a series of field and laboratory tests in order to determine efficacy and environmental effects (see PEA, TAMS 1989). A major environmental issue is the pesticide's persistence--and thus its potential for bioaccumulation and food chain-transport. Thus A.I.D has taken the position that dieldrin is unacceptable due to its high persistence (FAO, 1988c). A chemical which is desirable environmentally for its low persistence is less desirable for field operations because of the need to reapply that chemical. Extensive discussions within the donor community have examined this trade-off, especially for dieldrin which is persistent in the environment, and Sevin-4-oil (a carbaryl formulation) which must be rotated on a routine basis.

3.6.2 A.I.D.-Approved Pesticides

In the process for approval of pesticides funded by A.I.D. (see Chapter 2), the risk to non-target organisms and human health is balanced against the efficacy and appropriateness for field operations. As might be expected, different donor groups use different criteria in performing this assessment. However, donor coordination meetings have largely resolved differences.

The eight pesticides approved for use in the locust/grasshopper program, with cautions, are listed in Table 4.

TABLE 4: PESTICIDES THAT 1) CAN BE PROVIDED BY A.I.D., OR 2) ARE NOT APPROVED BY A.I.D. FOR LOCUST/GRASSHOPPER CONTROL

1) **Can be Provided:**

Pesticides that are **preferred choices**:

Malathion: avoid contaminating water
Carbaryl: avoid exposure to bees
Acephate: must be accompanied by a plan for generating data on efficacy and non-target effects

Pesticides that can be provided and **used with caution** and with appropriate mitigative measures:

Diazinon: avoid contact with birds
Fenitrothion: avoid contact with birds and all aquatic sites
Propoxur
Bendiocarb
Chlorpyrifos: must be accompanied by a plan for generating data on efficacy and non-target effects

Pesticides for which support can be provided **if contamination of water is avoided rigorously**:

Cypermethrin
Lambda-cyhalothrin
Tralomethrin

2) **Cannot be Provided:**

Pesticides that **cannot be supported under any circumstances**:

BHC
DDVP
DDT
Dieldrin
Lindane

Pesticides **under consideration but not approved**:

Deltamethrin

3.6.3 Alternative Pesticides

Several pesticides have not been reviewed or nominated for review in locust/grasshopper control programs. Deltamethrin is one such chemical. The absence of a pesticide from the approved list either indicates that its use has been rejected (as dieldrin, lindane and BHC) or that a review has not been done by A.I.D. The locust/grasshopper programs continue to evolve and it is expected that other pesticides will be considered for approval. In approving alternate pesticides, USAID seeks chemicals with up to moderate persistence, which do not present a risk from bioaccumulation or food-chain transport. Appropriate pesticide formulations must also be consistent in composition, and be amenable to field conditions (both as to handling and stability).

3.6.4 Donor Considerations and Problems Posed for "Non-Approved" Pesticides

In addition to major considerations about dieldrin (described in Chapter 3), the provision of other pesticides by other donors poses a series of managerial, training, and operational problems.

The managerial issues include coordination for proper placement and safety of the diverse chemicals that are donated. Particularly between FAO and A.I.D., conflict has existed over the need to ensure proper environmental controls and the use of pesticides on an "approved" list. Pesticides that have been approved under WHO, World Bank and FAO guidelines may satisfy some of the environmental concerns of the U.S. government, but sometimes they are not acceptable. FAO has continued a program of evaluating the efficiency of pesticides against acridids, and has developed a list of ca. 20 recommended products.

Uncoordinated use of different pesticides also poses serious training issues. Mismatching of pesticides or failure to properly clean equipment can lead to the clogging of sprayers and other equipment failure and incorrect application rates, with potentially hazardous consequences to personnel, the environment and crops.

3.7 Pesticide Applications

3.7.1 Minimizing Impact of Pesticides

By applying pesticides with knowledge of the area and its ecological significance, and carefully selecting pesticides from an approved list according to their expected or known impact (Table 2 and 4), negative impacts can be minimized. Generally, pesticides should not be applied to any habitat which is designated as a national park, a wildlife reserve or a critical area. There should be a 2.5 km buffer around such areas. Nearby aerial spraying should also be carefully monitored to prevent incidents due to drift. Areas to be sprayed need to be carefully marked. On-site ground observations should be made to assure that the correct area is being treated and that overdosing does not occur.

In addition, river, lake, and wetlands systems should be carefully delineated and pesticide use in the watershed areas or periphery should be carefully reviewed before plans for applying locust/grasshopper pesticides are completed. Generally, SEAs recommend that pesticide use should be banned or restricted near aquatic habitats. If a severe locust/grasshopper outbreak must be controlled near open water, it would be preferable to consider the use of acephate, which has a relatively low toxicity to aquatic life. Where wadis and their drainage lines suffer from locust/grasshopper invasion, and it is considered essential and unavoidable to incorporate them into areas being blanket-sprayed, swath lines and/or flights should be planned so that sections of the wadi or khor, say one kilometer in four (25 percent), are left untreated. From these reservoirs susceptible organisms may be able to restock depopulated areas.

In the Saharan zone, because of the vast expanses over which control operations do not normally take place, specific protection areas are not designated because affected biota can be replenished. In all areas, pesticide selection must operationally take into account the particulars of an area selected for treatment.

Monitoring can be significantly improved by having agents of the national wildlife service participate in locust/grasshopper activities so they can observe impacts on fiora and fauna. Raising the level of awareness among the public and farmers, but especially among CPS and government personnel should be part of A.I.D. programs.

Locust/grasshopper operations must give high priority to the identification of critical habitats and protected areas prior to commencing activity. Inventories of habitats, species and ecosystems should be accumulated. In most countries such inventories are only partially available. Where inventories do not exist, the country A.I.D. Mission(s) may designate their preparation. To accurately delineate areas scheduled for spraying, whether by land or by air, attention must be given to the logistics of delineation (survey, stakes, flags, markers, etc), and to the breeding time of the species to be controlled.

Usually, pesticides are essential elements in pest management programs. By using approved chemical compounds, and applying minimum dosage properly to targeted areas, pesticides are a short-term response to the build up of a particular pest species. Both ground and aerial application techniques are useful for control after a pest outbreak has occurred because they can be applied relatively quickly to produce rapid results.

Chemical and biological pesticides can be applied with several types of equipment, including bag dusters, hand crank dusters and sprayers, backpack sprayers and mist blowers; truck and tractor mounted sprayers, dusters, foggers; hand held spinning disc ULV sprayers, airplanes and helicopters of various sizes.

During outbreak conditions, the continuous movement of vast locust swarms over hundreds of square miles creates a situation beyond the control of the best organized ground treatment programs. In past programs, only aerial application was effective in controlling outbreaks of grasshopper/locusts.

Note that strategic control can prevent outbreaks and avoid the use of pesticides.

3.7.2 Ground Application

Ground application techniques are more precise than aerial techniques and allow flexibility in the use of personnel, but inefficiencies occur because equipment is often not calibrated correctly (Lloyd, 1959) and because the exact procedures for using equipment under a wide variety of circumstances are difficult to specify. Properly calibrated and used, ground equipment can give as good control of grasshoppers and locusts as aerial equipment and can compliment aerial applications.

To be efficient in large areas, the equipment must have ULV capability. In 1958 the exhaust nozzle sprayer was developed for use in desert locust control in Ethiopia. This device, still widely used in Africa, is attached to the exhaust of a motor vehicle and is the first successful machine to apply less than one pint per acre. Several ground sprayers also have ULV. These include the hand-carried battery-powered spinning disc sprayer, the ULV backpack engine powered sprayer, and truck-mounted mist blowers and exhaust sprayers. Other types of sprayers are also available (Overholt and Castleton 1990, and Symmons, 1991).

Use of insecticidal baits as an alternative to dusting or spraying has a long history, but the frequency of its use varies greatly. Baits appear to be most used in Senegal, where also some research into alternative carriers (millet, peanut, wheat bran, etc.) and feeding attractants and stimulants (molasses, various vegetable oils) has been carried

out (Niassey, 1990). Wheat bran is an ideal bait, and it is quite readily available in many Sahelian countries, because many of the countries, like Mali, have a wheat processing plant from which wheat bran can be obtained at a reasonable price. (A.F.D, 1991a).

Naissey (1990) recently reviewed experiences with the baiting approach, and evaluated several oils against the Variegated grasshopper (*Zonocerus variegatus*). He states that the use of baits is very economical and effective on a small scale, especially against nymphs. Its success depends upon accurate survey information so as to be able to identify and treat areas of concentrated hatching.

In Mali, an IPM project has undertaken preliminary investigations on the feasibility of baiting. Indications are that, in areas of higher millet production, the peasants may be prepared to use some of their excess or low-quality grain for the preparation of bait. In initial trials, baiting led to a reduction of numbers which was better than that achieved by conventional dusting.

3.7.3 Aerial Application

U.S. programs for locust/grasshopper control in Africa are built on the experience of the U.S. with grasshopper control from 1951 to 1963, in the northern Great Plains states. In the 1950s, ULV applications were developed in England using a spinning cage called the Micronair which produced a more uniform droplet size compared with standard boom equipment. When using non-volatile materials and flying at lower attitudes, this technique reduces the air residence time for droplets and reduces excessive drift. However, drift can be used to advantage on locust spraying where wide swaths can cover broad areas and fill in flight paths that are inexact. The advantage of this technique is that it allows greater coverage per spray tank. Also, use of concentrated materials directly eliminates the need for mixing formulation in the field and transporting dilution material (water or oil). Conventional application systems are somewhat inefficient in that they always produce non-uniform particle sizes, including a number of large droplets which can be wasteful of the pesticide.

In order to find a balance between careful control over areas sprayed and the efficiency of the use of aircraft, several types of aircraft are used. Small airplanes could average a 2000-pound load. The medium size airplane average nearly 3000-pound loads. Obviously with more load, the pilot can carry more fuel, thereby being able to make longer ferry flights to spray sites, but larger planes are less precise and are therefore not preferred.

Light twin-engine spray aircrafts are also used. They have good dual capability for carrying people as well as supplies. They have sufficient speed, range, and twin-engine safety for use in desert operations. Larger aircraft, including four-engine transports can be modified for spraying. They are suitable for operations where the distances to be covered and strategic considerations clearly require an aircraft with such long-range capability, and where the extent of the grasshopper infestation justifies their use.

Helicopters in a variety of sizes and capabilities may also be used. Most of the helicopters in agricultural use have small reciprocating engines. For ULV spraying, a number of helicopters could accomplish a considerable volume of work. Large helicopters, which can be used in a wider variety of loading sites in ULV applications, would compete quite favorably and economically with the larger airplanes.

For large variable size spray programs in Africa a variety of aircraft types may need to be used. Every job has a mix of requirements. Long ferry portions need a large aircraft; smaller treatment blocks closer to airstrips can be more economically handled by smaller aircraft. Helicopters having short turn ability are capable of treating many areas faster--especially areas without airstrips, areas that are sensitive ecologically or militarily, and small cultivated fields. For survey work in inaccessible and remote areas helicopters are a necessity. In some cases

helicopters must be used because the areas are vulnerable to spraying. An important component for safe/efficient use of pesticides is the training and certification of pilots in pesticide application.

3.7.3.1 Key Principles of ULV Application for Desert Locust Control

1. ULV pesticide systems are recommended for desert locust control by aerial means. They should be in effectively involatile formulations, which for logistic reasons should achieve satisfactory control at area dosages in the regions of 0.5 to 1.0 l/ha.

2. For air-to-air spraying of locusts in flight, small droplets are desirable. The spray system should be such as to produce as much as possible of the emitted pesticides in droplets smaller than 100 microns.

3. For settled targets,

   (A) **Maximum swath spraying**[1]. Substantial swath widths can be achieved in an acceptable steady cross wind above 2 *m/sec* measured at 2 *m*; 10 *m* flying height with a 150 *m* track spacing is a typical combination, with the appropriate aircraft and spray calibration.

   (B) **Minimum swath spraying**[2]. Targets can be treated in relatively still air with an appropriate calibration and track spacing, such as developed by USDA-APHIS for specific aircraft; for a Turbo Thrush, a 50 *m* swath and 10 - 15 *m* flying height is a typical combination.

For both methods, accurate track spacing is important. It is highly desirable that trained personnel monitor environmental conditions and efficacy. For both methods, emission of most of the pesticide volume in a droplet size band within the range of 70 to 125 microns is desirable in most situations. under certain conditions, larger droplets may be needed. Spraying should not be carried out in conditions of strong convection such as occur on hot afternoons, or under stable, still, and inversion conditions.

3.7.4 Scale of Operation

Even though efficiency-of-scale arguments can be made to favor aerial spraying over ground control, some evidence indicates that aerial spraying is less appropriate for the African countries. In general aerial spraying is a technology that cannot be supported very well with in-country expertise in Africa, and it consumes large amounts of foreign exchange (FEWS, 1987). The A.I.D. preference is to support the use of farmer brigades, ground control operations, and other local-control approaches. In the African context and with appropriate training, these approaches can be efficient and protective of the environment. Farmer brigades can perform well on *O. senegalensis* hatch sites within the peanut fields of southern Senegal. Most traditional methods are not applicable to a plague prevention strategy aimed at pre-upsurge populations showing gregarious tendencies. These operations may occur in remote desert areas far from agricultural areas.

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[1] Equivalent to the common term "drift spraying" as applied to locust control in Africa and Australia.

[2] Equivalent to "placement" or "precision" spraying, applied here in the context of an alternative locust spraying technique.

The locust/grasshopper management Operations Guidebook (A.I.D. 1989d) lists a guide to the size of the treatment areas for each type of equipment:

1-10 hectares	Dust bags, hand-operated dusters and sprayers
10-15 hectares	Compression sprayers, mist blowers
15-500 hectares	Vehicle-mounted ultra-low-volume (ULV) and exhaust-nozzle sprayers
500-2,000 hectares	Helicopters
2000+ hectares	Fixed-wing single-engine aircraft
5,000+ hectares	Large single-engine or small multi-engine aircraft
50,000+ hectares	Large multi-engine aircraft

3.8 Alternative Methods of Control

The natural cycles controlling insect populations, when combined with human efforts, provide mechanisms of balancing pest numbers with crop loss. However, under natural conditions that favor pests, populations overwhelm human efforts, and substantial crop loss can occur. Only in recent times has it become possible to use pesticides to deal with explosive populations of locust/grasshopper. Generally, widespread use of pesticides has been an effective means of controlling and curtailing locust/grasshopper populations. But with increased attention to the effects of pesticide use on the environment, alternatives are being explored.

3.8.1 Traditional Methods

Numerous traditional methods have been found to be effective, at some level, in the management of locusts/grasshoppers. Generally they respond to the nature of the locust/grasshopper life cycle and habits. Among these are the destruction of egg masses (usually by turning over the soil to expose egg pods, Figure 5), mechanical or manual trapping and crushing, digging ditches in front of hopper bands, and capturing for consumption. Other methods involve the release of locust/grasshopper consumers, such as chickens, into infested areas. Natural predators, such as birds, do exist, but the explosive growth of locust populations, coupled with their migratory behavior, would usually make this an ineffective means of control (i.e., the locusts reproduce much more rapidly than their predators and migrate suddenly beyond the predator range). However, in China, ducks and the like appear to have been used to useful effect against migratory locusts under certain circumstances (see Figure 6).

Using knowledge of insect food preferences, changing the times of crop plantings, planting crop strains that are more resistant to locust/grasshopper damage, and changing the nature of the crops planted (e.g., planting sorghum instead of millet) can reduce locust/grasshopper crop damage. Other techniques that have shown some effectiveness are intercropping, planting trap plants, and habitat control (such as keeping roadsides clear of weeds and plants).

A.I.D. favors a strategy that reduces or eliminates the use of pesticides for locust/grasshopper control in environmentally sensitive areas (e.g., watersheds, national parks, and wetlands). Thus, increased effort will focus on using these traditional methods more effectively for maintenance control of residual populations, and limiting crop loss in the case of explosive populations. This will require considerable education of the farming population, social and economic incentives, and technical assistance. Careful attention should be given to recognizing successful techniques of indigenous farmers who may have found ways to handle infestations on a small scale. For example, the simple act of spreading mosquito netting over trees can significantly reduce the damage done by tree locusts.

As a research procedure, egg-pods located during sampling are marked with toothpicks, and dug out individually.

Kraussaria, Hieroglyphus and Cataloipus grasshopper species lay their egg-pods at the base of shade trees.

The village team and their "bag" of egg-pods excavated in one day in the Senimana-Banamba area.

Sorting out the egg-pods and predator material collected during a general survey.

Figure 5. Excavating grasshopper egg-pods in Mali. Certain grasshopper species deposit their egg-pods in areas close to farmer's fields. By locating and digging up concentrations of such egg-pods, it is thought that villagers can significantly reduce the risk of damage to their young emerging crops. Village, or farmer (continued)
(Photos by George Popov)

A village brigade consisting entirely of women in the Dogon area, Mali.

Dogon brigade chief with grasshopper in fingers. Some of these people are able to place specific names on 15 species of grasshoppers. They also know which plants serve as oviposition sites for certain species.

Main use of village brigades (here in Karo, Mali) to date has been to manually apply pesticides, especially against first first generation early grasshopper stages. Many villages willingly join the effort, though safety equipment is not always available.

Dogon brigade with egg-pods in hands. Several of these brigades actively dig up egg-pods of Kraussaria. The practice is more prevalent where a local NGO trades 1 kilogram of cereal for each kilogram of egg-pods excavated.

Figure 5 (Continued). brigades have been formed by the hundreds in many Sahelian countries, mainly for crop protection purposes. Some of these brigades have also become involved in the excavation of egg-pods. The value of the egg-pod destruction as a preventative control method has not yet been fully validated, but evaluations done to date point to a clear potential under Sahelian conditions. (photos by Carl Castleton)

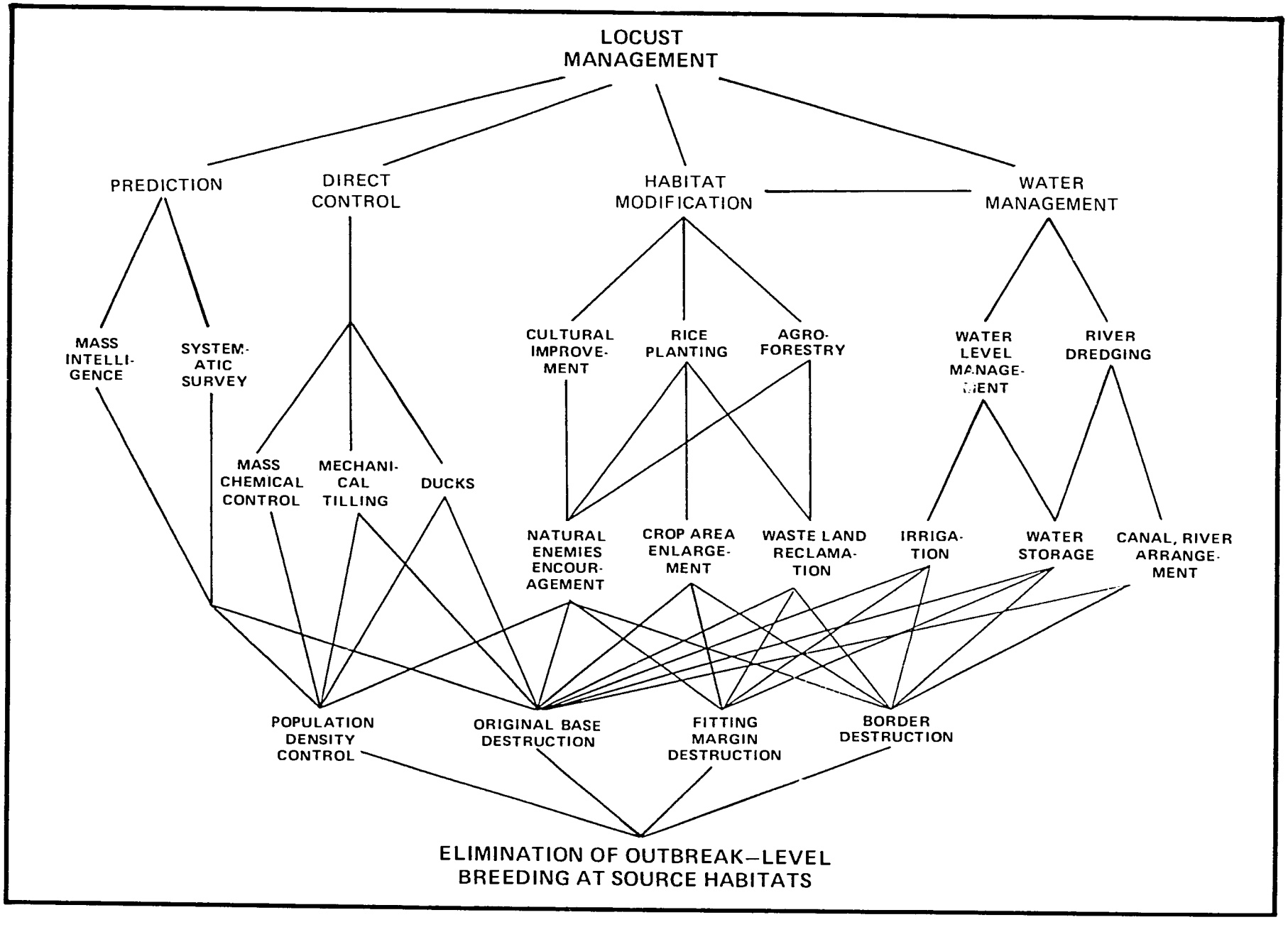


Figure 6. Illustrative linkages of an ecological approach to integrated pest management of migratory Locusts as applied in China: (adapted from a figure published in Hsien Fengnan (1974). Translated by Anghe Zhang and William Olkowski of the Bio-Integral Resources Center (BIRC), Berkeley, CA).

In Mali the following methods have been worthwhile: 1) trench digging to intercept gregarious larval bands, and 2) uprooting and destroying egg pods in certain species of grasshoppers. It has been reported that villagers in Mali know areas of high density for grasshopper eggs, where they could be dug up with minimum effort. Collecting *Kraussaria angulifera* egg pods by farmers during the dry season was instrumental in substantially reducing infestation in parts of the Dogon country (A.I.D., 1991a).

3.8.2 IPM and Research on Non-conventional Pest Control Agents and Techniques

Integrated pest management (IPM) is the preferred approach for pest control. IPM is not an alternative to the use of synthetic pesticides, but is instead an integration of methods which may reduce the use of chemical pesticides with emphasis on prevention. Appropriate and prudent pest management methods include the use of early warning and surveillance techniques, the establishment of economic thresholds, the timing of sprays based on best population dynamics, and the application of traditional or non-chemical control agents.

3.8.2.1 Remote sensing and greenness maps: early warning/monitoring systems.

Satellite-based weather, vegetation and land surveys and maps are all likely to be useful for building scientific and institutional capacity in African countries (U.S. Congress (OTA), 1990). Greenness maps have the greatest immediate potential for application to desert locust preventive control. However, problems with timely delivery remain. In addition, further field validation and refinements in spectral sensitivity are needed for maximum utility of greenness maps. Development programs in Sahelian Africa are beginning to use geographic information system (GIS) technology to produce seasonal vegetation maps made from satellite data to support grasshopper and locust control monitoring effects (Tappan, Moore and Knausenberger, 1991).

3.8.2.2 Anti-feedants.

Locusts and grasshoppers do not attack certain plants and are deterred from attacking others that have been sprayed with particular plant extracts. Such anti-feedants provide another approach to crop protection which is attractive because it utilizes natural products. Neem extract is being studied in a number of African countries and in the U.S. and shows some promise, especially in maintenance situations. Based on research by in Niger by GTZ (1991), exposure to small doses of neem oil causes dramatic flight disruption/knockdown and is considered to have the potential for disrupting the aggregation phenomenon in nymphs and adult desert locusts. However, in emergency situations, it would be difficult to get neem extract to infested sites on a timely basis (e.g., the rainy season) in sufficient quantities. Alone as an anti-feedant, neem extract would deter locust/grasshopper from attacking sprayed crops, but the pests would then attack unsprayed trees or crops. This aspect of neem use has not been explored.

Niger is currently the site of three neem projects sponsored by GTZ, the CIDA, and CARE. CARE has procured three mills for neem oil extraction. In addition, CARE has undertaken a study of small-scale enterprise opportunities for the utilization of neem products.

A.I.D. has also sponsored research on neem kernel extract, in cooperation with the Nigerian CPS. The research indicated that the neem extract would effectively repel grasshoppers (see Sect 3.8.2.3 below). Wide use of neem extract appears to be limited by constraints on available labor to produce and apply it, and the large volume needed for widespread effective control (Radcliffe et al. 1990, 1991). Projects under way should be used to guide additional research on neem.

3.8.2.3 Non-chemical or non-pesticidal.

Non-chemical means of control have been explored because they hold the promise of effective locust/grasshopper control with fewer environmental impacts than pesticides. The most extensively studied material is a microbial. *Nosema locustae* was tested in Senegal with indeterminate results (Henry et al., 1985). Preliminary results from collaborative trials in Cape Verde and Mali (A.I.D. with GTZ and Ciba-Geigy, resp.) suggest that *Nosema* is unlikely to be suitable for use in an emergency situation (Henry et al. 1990 in prep. van der Paauw et al. 1990). Availability of material and training applicators are also obstacles to widespread use. A possible approach is to pair *Nosema* with a pesticide, seeking to weaken the locusts through microbial attack and making them less resistant to chemical attack. Nosema may be useful for longer term use in an IPM context, particularly in those zones where pesticide use is restricted or prohibited. Investigation of large locust/grasshopper populations may reveal the presence of other microbials which could prove as effective as *Nosema*.

Other approaches utilizing non-pesticidal materials are the use of pheromones and kairomones. Little progress has been made to date in identifying these materials (which are generally species specific) and executing field studies. Synthetic growth regulators (e.g., diflubenzuron) are often considered "safe" alternatives to the conventional pesticides because of their different mode of action. Their effectiveness depends upon applications in the correct phase of the locust/grasshopper growth cycle. Precautions concerning environmental effects should be assessed because growth regulators may significantly affect non-target invertebrates.

Fungal agents such as *Beauveria* and *Metarrhizium* sp. are being investigated. In the summer of 1990, USAID carried out field trials on *Beauveria* near Mourdiah, Mali. Although these results were disappointing, studies in Cape Verde are more positive. Apparently certain basic research is needed on thermotolerance, histology of infectivity, strain enhancement, application methodologies and formulations. (Johnson et al. 1991, Delgado et al. 1991).

The practicality of using extracts of seed kernel from the neem tree, *Azadirachta indica*, as a locally-prepared pesticide for subsistence farmers in the Sahel to control grasshoppers and locusts on millet and sorghum was investigated in Niger, West Africa (Radcliffe et al., 1990, 1991). Entomological trials to evaluate the efficacy of neem kernel extract (NKE) against grasshoppers were initiated in August-September, 1987, at the Sahelian research station of the International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Sadore, Niger (Radcliffe et al., 1990). In the trials, neem kernel extract provided significant protection to sorghum and millet seedlings against 9 of 11 species of Sahelian grasshoppers and locusts tested. NKE was effective against *Acrotylus blondeli, Diabolocantantops axillaris, Kraussaria angulifera, Oedaleus senegalensis, Pseudosphinogonotus canariensis, Pyrgomorpha cognata, Ornithacris turbida cavosi, Chrotogonus senegalensis,* and *Schistocerca gregaria*; NKE was ineffective against *Cryptocatanops haemorrhoidalis* - primarily a forb feeder and *Oedaleus nigeriensis* - heavily parasitized. Locally-prepared NKE, from seed collected at five Nigerian locations (Naimey, Diagourou, Gotheye, Tsernawa and Mozague) proved as efficacious as alcoholic extracts. Accordingly, while the use of Neem technology for the protection of millet and sorghum crops is probably not feasible, we believe the NKE could have great potential for the protection of smaller plots of fruits and vegetables and the intensively cultivated counter-season crops and for protection of stored products.

The Grasshopper Integrated Pest Management Project (GHIPM) of the USDA-APHIS project is a five-year collaborative research activity seeking long-term solutions to rangeland grasshopper control with minimum environmental impact. With project sites of over one million acres in Idaho and North Dakota involving large tracts of land, GHIPM is designed to gather information for controlling grasshoppers with the most scientific, economic, and environmental safe methods available. This includes comparing conventual control methods with integrated methods involving both chemical pesticides and biological control agents such as insect pathogens.

Field operations are involved in the implementation and evaluation of grasshopper density reduction with several different methods in different types of environments. The project has identified a number of spacial and temporal environmental conditions which significantly contribute to population fluctuations. From this information, a data base and computer model have been developed to aid rangeland managers in strategic and environmentally sound grasshopper control operations. Future GHIPM efforts will further define the computer model and control methods to maximize population reductions while at the same time minimizing environmental impact (USDA-APHIS, 1991).

3.8.2.4 Egg pod survey.

For grasshopper management, the survey for, and destruction of, concentrations of egg pods represents a promising tool for control, prediction and planning. Major research efforts are needed to validate the predictive value of the surveys.

Popov et al. (1990) provide an excellent original treatment and review of this subject, and offer first rate identification guides to many of the key Sahelian species. Popov's report (1991) on a training course for "chefs de base" of the crop protection regions of Mali is also very informative.

Efforts to deal with grasshoppers occur in two main stages. End-of-season assessments of infestations and egg-pod surveys by the CPS are increasingly the basis for planning the early-season control operations, which are conducted mainly by farmers for the protection of early crops. Early steps taken are of a preventive nature: mobilization of peasants to dig up egg pods in and near their fields. As soon as rains begin, systematic control of hatching larvae is undertaken by village brigades, usually by dusting; at the early stages, the nymphs are very susceptible to control measures. The CPS gets involved only where it is its comparative advantage to do so (e.g., areas of difficult access, uninhabited areas, pastures) or if for some reason the control measures are beyond the capacity of the villagers to handle. Digging up of egg pods and early season ground control can have a significant influence on the subsequent development of the grasshopper populations in an area.

3.9 Pesticide Management

Good pesticide management requires careful storage site selection; good storage plans, a suitable inventory mechanism for tracking pesticide stocks; and an adequate method for disposing of old stock and empty containers. The challenge is to accomplish this despite often limited economic resources. Some elements of pesticide management are detailed below.

3.9.1 Labelling

Containers should be labelled at least as comprehensively as required by the donor country's laws, and in the official language of the receiving country (e.g., French or Arabic). Labels should include the date of manufacture or formulation to facilitate the control of stock obsolescence. Sturdy labels should be affixed to clean surfaces and then covered with resistant transparent tape. Other characteristics of labeling were discussed in the PEA. Consideration should be given to a common color-coding scheme to facilitate storage and assist handlers who may be illiterate.

3.9.2 Storage

Storage areas should be sited away from concentrations of people or animals, away from water supplies (e.g., community wells) and streams and their drainage areas, and outside flood plains. Each storage facility should be under the supervision of a trained person, and the facility should be fenced and locked with appropriate

warning signs, including signs appropriate for an illiterate population. At a minimum, materials should be stored off the ground on pallets or a concrete floor, with protection from the sun and rain. Where the facility is a building, there should be provision for adequate ventilation. Adequate supplies of clothing and equipment appropriate to the type of material stored should be on hand, as well as antidotes and first aid materials; these should be checked regularly by the supervisor. A supply of water should be located nearby, or stored at the facility, for use in washing and clean-up operations.

Most countries report deficiencies in the number and quality of storage areas. Resources should be directed to upgrade and maintain existing facilities, and to establish new ones which are consistent with good pesticide management practice. The Government of Sudan, with the assistance of the Dutch government, has rehabilitated 14 structures and built 15 new ones. The GTZ has also developed standardized plans for low-technology storage facilities. In Niger, 230 buildings have been erected at the village level, and there are plans for GTZ to construct an additional 690 buildings in the near future. USAID/Niger Financed 64 prefabricated storage units that are portable to be used at airstrips and for temporary storage at the department level. USAID/Niger is also investigating whether additional warehouse space is needed at the district and arrondissement levels.

3.9.3 Handling and Containers

Attention should be directed to improved training procedures to prevent or minimize spillage, particularly where there are transfer and formulation or dilution operations (e.g., airfields). Pumping equipment should be maintained regularly; dikes should be established around transfer areas or areas of large volume use; and where possible, operations should be carried out on concreted pads with lips. Absorbent materials should be available for emergency use, and plastic sheets should be employed before operations begin, to prevent contamination of soil.

Serious attention needs to be given to the establishment of container standards (gauge of steel, quality of closures, color of paint (white is preferable, etc.) to enhance the storage life of the containers (A.I.D. 1990b).

3.9.4 Transport

Much of the pesticide stock will eventually be distributed to remote areas where sophisticated or even common material handling equipment is unlikely to be available. Consideration should be given to the containers appropriate to those conditions, realizing that much handling may have to be accomplished by manual labor. In many cases the use of old tires for offloading barrels helps to avoid damage to them. Accordingly, the use of 200 liter drums should be minimized in favor of more easily handled smaller containers; these containers should be selected so that when empty they are not attractive for re-use by the local population. Bags of powders and baits should be appropriate for any handling by two-man teams, and should be of sturdy plastic material, both to prevent splitting in case of accident and to ensure storage integrity during a reasonable period of storage.

3.9.5 Obsolete Stocks

Central management and donor coordination of pesticide supplies will minimize the accumulation of obsolete stocks in the future. Currently, however, there are considerable stocks of obsolete or unmarked pesticides in all countries. These materials are left over from previous locust/grasshopper activities, including those which pre-date A.I.D. involvement, and include materials which are no longer intended (or approved) for insect control (e.g., BHC, dieldrin and lindane). Many of these materials came from other donor countries and through government purchases. Since some of the materials have been around for almost 30 years, the origin is not documented and, in many cases, labels and markings are no longer readable or exist. A current estimation of obsolete pesticide stocks was prepared for the West African Regional Pesticide Disposal Conference held in

Niamey, Niger, January 21-26, 1990 (A.I.D. 1990b). The materials, many in leaking and rusting containers, or crumbling bags and sacks, pose a potential threat to people and animals, and an indirect threat to water supplies. GIFAP (1991) provides a comprehensive review and discussion of currently available options for disposal of unwanted pesticide stocks, based on actual tested methodologies.

3.9.6 Disposal

3.9.6.1 Technical Issue

Numerous possible methods of safely disposing of obsolete pesticides exist, but none have yet been determined to be safe in practice. Some methods are practically impossible in the African context where there may be: no technical infrastructure; shortage of trained personnel; isolation of location and difficulty in gaining access; and lack of monitoring capabilities, both for short-term and long-term operations. Given the diverse nature of known and potentially unknown materials, and the fact that there are liquid and solid products, three possible options present themselves as practical in a short time frame. These are: burial in a secure landfill; incineration in a power plant or cement kiln (or equivalent); and transfer to another location for disposal by some other means (this includes long-term interim storage).

Any method chosen for disposal carries its own risks, which need to be identified in the context of site-specific and country-specific situations. Among these considerations are: potential threats to workers, to surrounding people and environment; and ability to establish reasonable environmental safeguards and monitoring activities. Against this must be balanced the present and increasing threat posed to the same targets by the continuing presence of large pesticide stocks in steadily deteriorating containers. Since much of this stock is already over 10 years old (and in one case almost 30 years old), the "no action" option is not viable.

Disposal in a secure landfill is the least attractive option for several reasons. First, the logistics of bringing in heavy construction equipment to many remote sites may be logistically impossible. Second, constructing the site to acceptable standards (with impermeable long-lived barriers of clay-like and synthetic materials) poses its own problems. Third, a secure landfill must have continuous monitoring, with reasonable alternatives in the event of barrier-leaks. Further, this approach requires a long-term commitment. In the present African context, characterized in many cases by extended civil and national wars, and the general deterioration of infrastructures and economies, this level of long-term commitment is very problematic. Fourth, the establishment of a secure landfill presumes a thorough hydrogeological study such that important aquifers will not be endangered either by construction or by the failure of a liner. Again, this represents a level of expertise and cost that is questionable.

3.9.6.2 Incineration

Incineration of obsolete pesticides seems to offer the best balance between risks of doing nothing or waiting for sophisticated technological solutions, on the one hand (with attendant dangers to people and the environment), and utilizing technologies and resources that may be available, on the other hand. For example, Sudan has disposed of all its liquid pesticidal wastes using a portable commercial incinerator. (Studies supported by A.I.D. were to have been conducted utilizing a cement kiln for the destruction of solid pesticides, but this was initially halted because of flood, and subsequently by governmental issues.)

A demonstration program for the terminal destruction of aged pesticides was recently conducted in a cement factory in Pakistan (A.I.D., 1990a). The objective of this project was to demonstrate destruction efficiency and environmental safety while maintaining quality of cement production. Twelve thousand liters of organophosphate and 5,500 liters of organochloride pesticides were incinerated during the normal process of cement making; they were injected at rates of 1.3 to 3 liters/minute. Analyses showed that emissions of pollutants did not exceed

standards set by the Environmental Protection Agency of the Punjab. Destruction removal efficiency exceeded 99.99%.

Consideration should be given to utilizing the power plants and kilns in specific countries to destroy obsolete pesticide stocks in an environmentally acceptable manner. The costs of moving a portable commercial incinerator from place to place is probably prohibitively expensive. But, if a commercial incinerator already exists in a country or region, careful consideration should be given to modifying such a facility to serve as a pesticide disposal unit.

Alternatively, materials could be removed from one country and safely sent to another country with an appropriate disposal facility. This may be an option for countries which lack a power plant and/or cement kiln. The safe transfer of liquids from leaking drums to stronger drums, and the transfer of solids to secure packaging, can make this a relatively safe option with identifiable risk to the environment. The use of overpack materials can be used for difficult cases. This same strategy could be used to safely move materials from remote areas to an incineration site within a country. Logistics should be planned for transport during the dry season to minimize the risk of accidents.

As an example of an approach to on this problem, USAID/Niger and the Niger CPS are cooperating in efforts to reduce the risk posed by unusable stocks of dieldrin. This cooperation has resulted in the centralization of dieldrin stocks in two locations in Niger and the development of a draft "Phase II" plan for further risk reduction activities. A number of options for the long-term management of the dieldrin stocks, ranging from complete destruction to long-term storage, were investigated by A.I.D., CPS and the manufacturer of dieldrin, Shell Chemical. This resulted in a collaborative venture proposed by Shell and financed by Shell, USAID, and GON, the Niger Dieldrin Disposal Program which in 1991 successfully rid Niger of 54,000 liters of dieldrin - the entire known stock in the country. The dieldrin was transported by truck and boat to Holland where the pesticide was destroyed in a high temperature incinerator.

In addition, A.I.D. and the Government of Niger sponsored a Regional Pesticide Disposal Conference in Niamey in January, 1990. Participation in this conference enabled the CPS to begin assessing the nature of the unusable pesticide problem in countries across the Sahel and to begin to develop a plan to address this issue. The conferences also helped build professional networks within the locust/grasshopper management community.

Once the existing stocks have been destroyed, central management of pesticide stocks, together with new strategies requiring less pesticide use, and policies aimed at reducing unnecessary pesticide use, should prevent the recurrence of this problem.

3.9.7 Empty Containers

The problem of empty containers is mainly focused on 200-liter metal drums because local populations find them a scarce resource for which they can find many uses: cooking, food and water storage, roofing and siding, and fencing. The threat to humans and the environment arises because these containers often have pesticide residues and are seldom cleaned after use; their domestic use provides a potential point of entry of toxic materials to humans and the environment.

Because of the known risk of human poisoning where "empty" pesticide containers are used to store drinking water or food, and despite some potential beneficial use of these containers, A.I.D. has evaluated the risk and has determined that the drums must be rinsed, punctured, crushed and buried (TAMS, 1989) or decontaminated/recycled. Destruction of drums is official policy.

The current general policy of rendering the drums unusable by piercing with holes and flattening is not extensively practiced. The high value of these containers on the local market and the general absence of drum flattening machinery hinders implementation of this policy. Furthermore, after such mechanical control the drums still must be buried in a secure landfill. This is seldom done because of the problems of digging pits deep enough and providing the secure barriers to groundwater impact.

Since the pesticides are distributed through national crop protection services which have final distribution points above the hamlet or village level, it is difficult to clean drums immediately or return them to a distribution point for cleaning. Initial cleaning can be accomplished by the systematic draining of drum contents into receiving drums as soon as possible after use. Subsequently, each drum can be rinsed several times with small portions of solvents or detergents, and the rinsate collected with the initial drainings. Water, solvents, and detergents necessary for this purpose can be shipped with the pesticides. The volume of such materials could be as low as 2 percent of pesticide drum volume. The rinsed drums (imperfectly cleaned but now much less of a threat) and the rinsate can be returned to the closest distribution bases in the vehicles that brought the filled drums, or held until later in the dry season when replenishment supplies are brought in for the new year. The rinsate then must be disposed of in the same manner as obsolete pesticide stocks. Such strategies reduce significantly the threat to people (since the pesticide residues in the drums will be much lower) in case of pilferage and subsequent domestic use, or to the water supplies in the event of landfill disposal. However, implementation of drum cleaning may be difficult if local water supplies are limited.

The preferred solution is to return the drums to the main distribution center for thorough cleaning and recycling. Recycled drums should be marked clearly. This is especially attractive in those countries, like Senegal, which have a commercial manufacture and recycling center; it is also attractive for those countries which do their own formulation for a range of crop protection products as well as locust/grasshopper control. In any case, centralized cleaning programs can lead to reduced hazards and to some income from the sale of cleaned drums or metal material from drums to the local market. In those cases where the volume of drums is large, relatively low cost and efficient drum cleaning machines are readily available from the commercial market. A.I.D. needs to ensure that drum cleaning is being implemented.

Given the practical considerations of providing pesticides to remote areas and attendant problems of cleaning and disposal or reuse, the use of impervious liners in drums merits attention. After removal of contents, the liners can be removed separately, leaving most surfaces relatively clean. The liners can be put into a separate drum for safe disposal. Some American and Australian producers are already using this packaging approach.

Finally, the problems of disposal would be lessened if there was an agreement to use only a few kinds of pesticides in each country, resulting in standard methods of cleaning.

A.I.D./Niger has developed a draft "Prototype Barrel Disposal Plan" for barrels which have contained organophosphate pesticides. The plan has been submitted to the CPS, GTZ, and CIDA for review and comment. The plan will receive a careful review to assess the technical and procedural viability and safety of the proposed methods and procedures, evaluate the appropriateness of the equipment, and determine the necessity (not suggested in the plan) for removal of the crimp in the barrels. The draft plan suggests the use of the decontaminated containers as fences, road markers in desert areas, and young tree protection. As the result of the review, the safety of these uses, and others which might be proposed, would be assessed and modified as appropriate. Experience with A.I.D. drum disposal efforts in Morocco should also be evaluated for application to other countries (Keith, 1988; Pritchard, 1989).

3.10 Human Health

A corps of qualified and competent health professionals exists in each country, and in major facilities such as hospitals. Nevertheless, the overall level of health resources is below WHO levels, especially in rural areas where pesticides are used most frequently.

3.10.1 Public Health Infrastructure

The public health infrastructure is fairly consistent and pyramidal in nature throughout the countries of the Sahel. In capital cities and major population centers there are hospitals, physicians, nurses and related health professionals. In towns, the next level, there are clinics often staffed with a physician, several nurses and paraprofessionals or technicians. These towns are often the administrative centers for districts or regions, or major market or trade centers. In the villages, there may be a nurse and a few paraprofessionals. Finally, smaller villages and hamlets have a scattering of paraprofessionals.

All health care personnel should be trained to recognize the symptoms of pesticide poisoning and on the appropriate response steps. In the most remote and smallest villages, poison victims may need transport to the nearest health center with a nurse. All certified nurses in the agricultural areas subject to locust/grasshopper infestations should have training in symptom recognition and in emergency treatment. Appropriate antidotes should be stocked routinely and replaced regularly to always ensure effective antidotes. In particular, when a major locust/grasshopper effort is to be mounted, health service personnel must be notified and extra supplies of antidotes stocked. Most cases of poisoning will respond to antidotes, rest, and removal from additional exposure to materials, but all health personnel should be aware of the means by which an acutely ill person can be transported to the next higher level of care. Ensuring the existence and availability of such means is an important responsibility of the managers of the locust/grasshopper campaigns. In particular, the national CPS should work in close conjunction with the health ministry to coordinate training and response actions.

Appropriate materials should be developed, both in the local language and in poster form for use at the lowest levels of the health pyramid. In addition, materials should be developed for use by the general public during locust/grasshopper campaigns to help recognition of pesticide poisoning symptoms.

3.10.2 Measures to Avoid or Mitigate Impacts

3.10.2.1 Avoiding Populated Areas

The avoidance of populated areas during spraying represents a major preventive action. Spraying should not take place within a 2.5-kilometer buffer around population centers, and every effort must be directed to having the applicators aware of the possibility for drift. It should be clearly understood that local weather conditions will determine whether scheduled spraying will actually take place. People should be advised to cover wells and outside water sources, food, and to remove animals within the buffer zone. Nomads should be made aware of scheduled sprayings and their movements monitored in advance of the spraying. All people should be advised to avoid the sprayed zone for as long as feasible, with two days being the minimum. Further protection will be gained by a diligent process of marking (flagging) areas to be sprayed, so that the aerial sprayers will have clear targets and people can determine what has been sprayed. The addition of a colored dye to the pesticide formulation might also help to identify contamination. Information dispersed by local radio broadcast has been effective in the past to achieve these goals.

3.10.2.2 Public Awareness

Public awareness of impending locust/grasshopper activities should significantly reduce exposure to pesticides. Among the most effective means are the use of posters, oral communication through CPS agents and the village leadership structures, and the use of radio programs which have coverage over wide areas and which are very popular. People should also be made aware of the need to refrain from harvesting crops before an appropriate interval has passed after spraying, refrain from eating products which could have been exposed to spraying (e.g., garden produce), and especially to refrain from eating locusts made available in the aftermath of a spraying operation. Since locust consumption is a common food source, this may need some explaining. The health professionals at the lowest level of the health pyramid can perform an important service by educating people about the dangers of pesticide residues, particularly in locusts. In Niger, in 1987, there were reports of persons becoming seriously ill from eating locusts and grasshoppers. Samples purchased in the Niamey marketplace and then analyzed indicated contamination with the pesticides dieldrin and BHC. Government border stations and residents of neighboring countries should be alerted to the possibility of importation of locusts and grasshoppers which were killed in other countries (by locust/grasshopper operations) and might contain pesticide residues.

Most countries lack suitable facilities to quickly and routinely test materials for residues. When analytical facilities become available, analysis of random batches of foods should be conducted to verify the after-effects of spraying operations, and to ensure public health by preventing contaminated materials from entering the food distribution network. In the meantime, the lack of verification capability is one more reason for emphasizing prevention rather than control with pesticides.

3.10.2.3 Applicator Safety Precautions

Probably the majority of exposures to, and poisonings by, pesticides occur as a result of occupational exposure, particularly among pesticides formulators, handlers, and applicators. Workers should be educated as to the three routes of exposure (dermal, ingestion, and respiratory) and the steps to take to minimize such exposure. Among the easiest protective precautions are face masks, long-sleeved shirts and pants, and shoes or inexpensive disposable foot covering, which should be retrieved for safe disposal. It may be necessary for the CPS (with A.I.D. assistance) to provide exposed workers with identifiable appropriate clothing and to replace or wash the clothing during the application season. This might also have a secondary effect of increasing the sense of control activity among local populations, improving the morale of the applicators, and providing a small economic benefit to the workers.

3.10.2.4 Cholinesterase Testing

Testing of cholinesterase levels should be initially limited to those who handle organophosphate compounds on a regular basis. Such personnel might include formulators, handlers, and CPS spraying personnel. For effective monitoring, tests should be conducted at the beginning, middle and near the end of the campaign. All workers should be educated as to the symptoms of poisoning, and encouraged to report symptoms to supervisory personnel. All supervisory personnel should have considerable education in the matter of poisonings, and understanding of the importance of removing workers immediately from exposure if symptoms are presented. Affected workers displaying low cholinesterase levels must be removed from exposure until acceptable levels return. Further, supervisory personnel must assume the responsibility to get the affected worker to the closest health professional as soon as possible for observation and possible further action. Economic disincentives for the self-reporting of symptoms should be avoided. The routine cholinesterase testing of the general population is not efficacious at this point.

3.11 Training

The goal of A.I.D. participation is to assist countries to move to self-sufficiency in locust/grasshopper control. In order to be self-sustaining purposes, programs must be simple and utilize appropriate technology tailored to the country situation and resources. The question of financial sustainability is a serious issue in the Sahelian countries; programs should have the lowest possible recurrent costs to ensure long-term program life and success. Training can promote self-sufficiency.

3.11.1 Country/Crop Protection Services

All the Sahelian countries organize locust/grasshopper control in similar ways. Responsibility is generally vested in a Crop Protection Service (CPS) which is part of a government ministry; the ministry coordinates with other government ministries as appropriate (for example, in matters affecting national parks and importation of materials). CPS personnel may be divided into three categories: those who deal only with locust/grasshopper activities; those who have locust/grasshopper and additional responsibilities; and those who have no locust/grasshopper responsibilities. The objective is to have a national CPS which accepts responsibility for locust/grasshopper control within the context of a broader crop protection program. This would ensure efficiency in total pesticide management, personnel development (including training), and use of resources (including equipment).

A typical CPS is organized in a pyramidal fashion, with a well-trained cadre of professionals operating from a capital city and having a section devoted exclusively to locust/grasshopper control (at least during times of plagues). Further levels of the organization are broken down into regional, district, town, and village and hamlet level. Trained CPS personnel are usually found at the district and town level; locust/grasshopper activity at the lower levels is generally under their supervision but is led by local village personnel who provide the structure for farmer brigades. It is clearly necessary for the CPS to provide continuous technical leadership so that direction for the brigades can be maintained and improved. Constant training is required to achieve this.

CPS training programs need to recognize the long-term nature of locust/grasshopper control, the turnover of personnel by retirement, the attraction of other work opportunities, and the movement caused by lack of opportunities. Given that locust/grasshopper control should be based on maintenance activities during the long recession periods with capabilities to provide an infrastructure for plague responses, it is urgent that the accumulated memory of control efforts not be lost during extended recession periods. Accordingly, full response efforts must be practiced by all key CPS personnel on a regular basis rotated among all staff so that during a triennial period all personnel associated with, or likely to have such responsibility for, locust/grasshopper control activities will have at least one period of extensive field training. Such knowledge must also be effectively transferred to the village personnel where appropriate.

The need to maintain a knowledge base and high levels of appropriate expertise is a challenge given the often limited resources of the countries. Although improved compensation is usually not a viable approach to maintain long-term personnel commitment, increased professionalization and spirit-building through frequent training opportunities, workshops, and regional conferences within the country are feasible. Since locust/grasshopper control often takes place in a multi-national context, the establishment of regular conferences devoted to training and networking among the locust/grasshopper professionals in regional groupings of countries would be a cost effective way of maintaining high-degrees of readiness and technical competence.

Training could be focused, among others, on the following topics, adapted to local conditions and locust/grasshopper species:

1. Insect identification, including immature stages;
2. Field survey and delineation procedures;
3. Integrated pest management;
4. Ground application techniques;
5. Aerial application techniques;
6. Health and safety issues;
7. Pesticide trials;
8. Utilization of economic criteria in decision-making;
9. Public education;
10. Management of logistical operations, for supervisors;
11. Strengthening of farmer brigades and CPS terrestrial operations; and
12. Proper storage and disposal of pesticides.

As an example of training opportunities, a number of workshops have been held in Niger on application techniques. The CPS held a workshop on aerial pesticide application in Tahoua from May 14-17, 1989. A.I.D./Washington, A.I.D./Niger and FAO funded a regional training course on safe use, maintenance and supervision of aerial and ground ULV applications in April, 1989 and on training materials development in May, 1989. In June, 1988, a five-day workshop was held in Niamey for Sahelian heads of field operations; the workshop focused on the use of Micronair exhaust nozzle sprayers and TIFA equipment. Emphasis was placed on how to use oil sensitive papers to monitor droplet size and swath widths. CIDA is also funding courses in application techniques for CPS personnel.

Another example is the seminar on "Health Aspects of Pesticide Application," held in Bamako, Mali in May 1989. Since both CPS agents and public health personnel attended, the workshop provided a forum for interagency interaction. Such interaction is extremely beneficial in sharing knowledge and effective in achieving mutual goals, and should be encouraged wherever possible. In a similar fashion, there should be as much interchange among the locust/grasshopper specialists and other CPS field and staff personnel as is possible. Interagency communication is consistent with CPS responsibility for ensuring locust/grasshopper control within the context of a broader crop protection program in the country.

The use of many different pesticides in different formulations is a serious impediment of safe pesticide management and effective pesticide use. In principle, each different formulation should be applied at a different dosage and involves different levels of precautionary measures. Equipment also varies. Proper calibration and use of equipment is extremely difficult under African circumstances. Improper calibration greatly increases the risks of negative effects to the environment and to the applicator, and decreases the cost-effectiveness of the locust/grasshopper control program. Constant training would minimize these problems, and provide a constant pressure to standardize materials, equipment, and procedures; feed-back from field personnel in training sessions to CPS leadership and to donor country coordinating groups could be effective in mitigating these issues. In addition, donor coordination in denoting pesticides and equipment would be a great help.

Transferring knowledge of materials, equipment and techniques to non-CPS personnel at the village and farmer level is a key challenge to front-line CPS personnel. Again, because of the need for sustainability on the one hand, and safety and effectiveness on the other, constant training of farmer brigades is required. Coupled with CPS efforts in non-farming areas they form the backbone of maintenance efforts in recession times. Every effort must be made to keep methods simple and consistent, and to monitor the equipment and the formulated materials.

At the village level and the lowest points on the CPS structure, equipment must be checked for efficiency and calibration on a regular schedule.

3.11.2. A.I.D. Mission(s)

Technical personnel and technical assistance teams should be given short-term, intensive technical training (including language, if necessary), and some background in the use and availability of training aids. In addition, each mission should be constantly seeking to identify issues that could assist in the transition to self-sufficiency, keeping in mind the need for financial sustainability. For example, since improved surveillance activity is central to current locust/grasshopper control strategy, workshops on field radio communications and radio repair would be useful. Indeed, radio repair might well be efficiently carried out at facilities determined on a regional basis.

CHAPTER 4
IMPLICATIONS AND PREFERENCES FOR FUTURE ACTIONS

4.0 Issue IV: Environmental Aspects of Future Assistance Programs

A.I.D. now intends to incorporate lessons learned from past programs and recommendations from outside reviews into planning for future assistance programs, with special emphasis on locust and grasshopper preventive control. A.I.D. has been involved in providing aid to African nations for protection of agriculture from locusts. These programs now must be consistent with environmentally sound approaches. A.I.D. seeks to be responsive to recommendations in (1) the Report to Congress by the Committee on Health and the Environment (Conservation Foundation, 1988), (2) the Programmatic Environmental Assessment (TAMS, 1989), (3) the mid-term evaluation of the AELGA project (Tropical Research and Development, 1989), (4) the Office of Technology Assessment report on locusts (U.S. Congress (OTA), 1990), and (5) the individual draft Supplementary Environmental Assessments. The vision of the future that forms the framework for these efforts consists of seven major components, which are discussed below with respect to environmental issues.

4.1 Approaches to Minimizing Pesticide Use

Since pesticides have the potential to damage the environment, risk is reduced by decreased use of pesticides and prudent selection of those pesticides that are used. IPM major components of this approach are covered in the following seven items. The A.I.D. approach should emphasize integrated pest management (IPM).

4.1.1 Integrated Pest Management (IPM)

A.I.D.'s preferred approach to the management of locust/grasshopper populations is IPM. This approach does not focus solely on any one tactic in dealing with locust/grasshopper populations. Since the current preferred method relies heavily on chemical pesticide applications, the utilization of IPM represents a redirection of existing resources. The goal is to control locust/grasshopper populations in the most effective manner consistent with minimal environmental impact. Thus, all available methods (including pesticide selection) will be considered and utilized to result in the least amount of chemical application in the least amount of area.

Increased use of traditional and other non-pesticidal methods, integrated with other management methods, is envisioned. In addition, an improved surveillance system should lead to better definition of infestations and permit thoughtful evaluation of the potential for explosive outbreaks. When an outbreak is imminent, pesticide applications can be considered. IPM also includes components of modeling, survey, geostatistics and sampling. Use of economic thresholds and correct timing of sprays based on pest population dynamics are among the examples of modern and prudent pest management methods. Using these methods will prevent overreaction to presumed outbreaks, and should permit more effective and minimal use of pesticides. Once research and testing have indicated the effectiveness of non-chemical approaches, such as the use of insect growth regulators or pheromones, these could become part of the standard control methods.

4.1.2 Preventive Control

Experts believe that locusts can be held in recession indefinitely by vigorous surveillance and timely preventive control. Though this approach seems expensive during periods of recession, the vigilance pays off in the future by avoiding expensive emergency operations at a regional level and by protecting the environment from large-scale uses of pesticides applied to protect crops whenever they are at risk. A.I.D., in principle, supports the

strategic management concept explained in the FAO Interregional Preventive Control Plan (FAO 1989b, 1991). A recent paper has reviewed the use of strategic control during the past locust plague (Showler and Potter, 1991).

4.1.3 Improved Conservative Decision-Making Criteria

Despite limited and/or poor data on crop loss and uncertain economic thresholds for intervention, the prudent approach is to withstand political pressures for quick fixes to the maximum extent possible. Hasty actions precipitated by the widespread presence of large numbers of locust swarms may not only be environmentally detrimental, but also economically unjustifiable. For instance, locust populations which cover hundreds of hectares but are below threshold densities for action and which are presently situated away from crops, have no certain economic importance. The position of the swarm with respect to environmentally sensitive areas, and logistical considerations (including adjacent crops) need to be considered in decision-making. A.I.D. should employ decision rules that err on the side of restraint in applying pesticides.

It is usually cheaper to prevent an environmental problem than to fix it later.[2] By instituting reasonable standards and mechanisms for oversight of the industrial and agro-industrial sector major environmental problems can be prevented in the future. In the case of agrochemical pollution, and many of the waste management issues, systems can be set up for the proper handling of obsolete stocks of pesticides, and empty drums.

4.1.4 Developing Self-Reliance

A.I.D. aims to contribute to the development of self-reliance. In principle, A.I.D. will support institution-building activities in developing countries, pesticide safety training that is transferable to other programs, the use of traditional or non-chemical methods that are under local control, and contributions to infrastructure development.

The peasant village brigades (Figure 5) can play the main role in campaigns, through, for example, surveillance, communicating observations, destroying egg pods, controlling larval bands -- if the time and effort are put forth to train them. Training for peasant awareness has been a generalized operation since 1985 in the zones where the locust/grasshopper problem is characteristically endemic, but the training of intervention brigades at the village level started one year later.

These brigades, usually composed of ten young people chosen during awareness training, go through training (of approximately three days) that is rather advanced in the amount of information given them. They receive a certain amount of pesticides (typically 5 percent a.i. or less in powder form) and a portion of treatment and protection materials. These young people receive follow-up training from the Plant Protection staff and are responsible for control operations at the village level. As ULV concentrates and ULV hand-held sprayers are introduced, it becomes increasingly important to strongly emphasize pesticide safety, and the use of pesticide protective equipment. A regular program of re-training should be an integral part of village brigade development.

[2] For instance containing a chemical waste in a factory is far cheaper than putting it into a landfill, which may contaminate the soil, air, surface and groundwater. Not only do the pollution problems spread, leading to a need to treat greater quantities of waste, but the techniques needed (drilling wells for example) are more expensive. In developing countries, a nation needs to evaluate the relative cost of the environmental cleanup over time--perhaps a more expensive cleanup can be better afforded by a more prosperous nation in the future. Also there is the opportunity cost of using capital for cleanup when it might also be used in industrial investments. However, in all cases known, the cost of "cleanup later" is growing far faster than the growth rate of countries with reasonably robust economies.

This training is most active in outlying areas away from centers of activity such as Haute Vallee Mali (where parastatals and development agencies already operate, thus awareness is likely to be greater). During 1989, about 224 village plant protection brigades were trained, and in 1990, about 446, or about 2,240 and 4,660 peasants, respectively (S.P.V. 1991). These village brigades and other trained farmers are assuming an increasingly important role in the national plant protection scene, consistent with the objective of decentralization. However, limited access to pesticide safety equipment and training remains a concern.

4.1.5 Avoidance of Protected Area

Ecosystems in Africa are under stress from a number of sources and are vulnerable to environmental impact from insect control operations. A.I.D. is firmly committed to avoiding actions which add to those stresses. Areas that have been designated as belonging to a protected category--national parks, wildlife reserves, and all wetlands areas -- should be kept free of A.I.D. - supported pesticides regardless of how well or how poorly those resources are protected from other sources of stress. Avoiding protected areas will provide some safety for Africa's unique mammals and birds, and will increase awareness of the need for protection among the governments of developing countries. In addition, it will provide refuges for the development of natural diseases and parasites of locusts and grasshoppers.

4.1.6 Reducing Uncertainty

A major difficulty in working on African problems is the lack of information sources. A.I.D. should emphasize the need to improve the collection, maintenance and use of information in all areas.

Databases are inconsistent and insufficient for planning environmental conservation. Where these databases are substantially complete, no integrated coordination of data is readily available in computerized or tabulated format. This lack of data coordination also extends to the limited communication between different government sectors. Processes need to be developed to collect and analyze information. For planning, a formal process is needed to examine the environmental consequences of a proposed project. For example, the establishment of an environmental assessment process. The process needs to be implemented in appropriate sections of a national economic development plan and may apply to industry, water resources, urban, coastal areas, irrigation sites, agricultural sites and food storage areas. A more complete database on natural resources at risk, and their location with respect to other activities may allow better protection of these resources, without unduly inhibiting economic growth.

4.1.7 Developing Alternatives to Chemical Pesticides

A.I.D. recognizes the paucity of alternatives to synthetic chemical controls. Traditional methods are not adequately studied and their effectiveness not fully evaluated, and biological methods may not be appropriate in the African context. Yet, non-chemical tools have the greatest potential for reducing reliance on chemical pesticides. Recognizing this, A.I.D. should continue support for the development of non-chemical methods of locust control.

In order for locust and grasshopper control programs to focus on plague prevention, it is necessary to fully develop known methods of monitoring and integrated pest management. This is by necessity a long term process which needs to be integrated with and grow out of the existing program. A report by Congress (U.S. Congress (OTA), 1990) states that the U.S. agencies must not simply react to crisis situations (crisis management), but must develop sustained programs that will be more efficient and less damaging to the environment in the end. A

forthcoming report, (FAO, 1990c) should help identify principal high-frequency danger zones where breeding and infestations occur and should facilitate both early detection and reductions in pesticide use.

A comprehensive FAO report (FAO 1988d) assesses research priorities relevant to desert locust control and plants and proposes focusing on semiochemicals, crop loss assessment, survey and monitoring methods (especially early warning), and innovative control tactics. The report is emphasizing that these activities would lead to practical applications. The report deserves careful evaluation in future planning.

Neem research has been progressing. Schmutterer (1990), and Radcliffe et al. (1990, 1991) have recently completed reviews of field applications, and GTZ (1991) has had promising results in Niger. Possible uses of semiochemicals have been carefully reviewed for the Norwegian Ministry of Development Cooperation (Bie, 1989) among others. The report emphasizes the importance of controlling locusts and their breeding areas by using chemicals that interfere with the mechanisms responsible for phase transition, for example, using detailed population dynamics models for forecasting, and pheromones and hormone control.

Kairomones, which are short range attractants and feeding stimulants, could be incorporated into feeding baits laced with toxicants, pathogens or growth regulators. The desert plants *Schouwia* in the Western Sahara and *Tribulus, Aerua, Cenchrus* and *Indigofera* in India are plant insect-hosts which might contain specific chemicals for feeding attractants and feeding stimulators.

Allomones are repellent or deterrent compounds which could be used to protect crop plants from destruction, or to divert locusts towards trap plants. Identification and isolation of the genes producing these plant compounds may allow the greater use of transgenic plants to trap locusts. The main problem with trap plants is that the species preferred by the locust are commonly preferred by cattle and game animals as well. Grasses imported from Mali to Australia to improve pastures turned out to be favorite species to locusts.

Pheromones are natural substances emitted by insects to regulate group behavior and may disrupt the gregarious phase of locusts. Hormones are produced by certain plants as part of their tactics against herbivores. Hormone analogs found in desert plants have been shown to be important for the development and fecundity of locusts (Odhiambo, 1988). Several have been proposed for population regulation of locusts and grasshoppers (ICIPE, 1988) as follows:

A gregarization pheromone initiates the crowding and aggregation of locust grasshoppers, and induces them to form bands of grasshoppers and later to swarm as adults. Maturation pheromones accelerate and synchronize the sexual maturation of both sexes. Oviposition pheromones aggregate female locusts to the same egg-laying sites and stimulate mass egg-laying. Solitarization pheromones promote some solitary characteristics and may be used to disperse locusts. Maturation-inhibiting pheromones inhibit or delay sexual maturity. Juvenile hormone analogs and anti-juvenile hormones, which control maturation and feeding, have also been proposed.

Evidence presented in the PEA suggests that pesticides have been used extensively. Pesticides are used in health programs, agriculture, and in special control programs (which include locusts and grasshoppers). Widespread pesticide use has recently been documented for Mali (Peckam, 1990; Peckham and Cooper, 1991). Some may interpret these findings on large-scale use of pesticides as a rationale for continued overuse in locust campaigns because there is far wider use elsewhere (Figures 7 and 8). However, the locust/grasshopper program should provide an example for environmental conservation and serve as a forum for environmental concerns. As locust programs move towards preventive control, they may also bring pesticides to isolated areas that may not now be exposed to pesticide use.

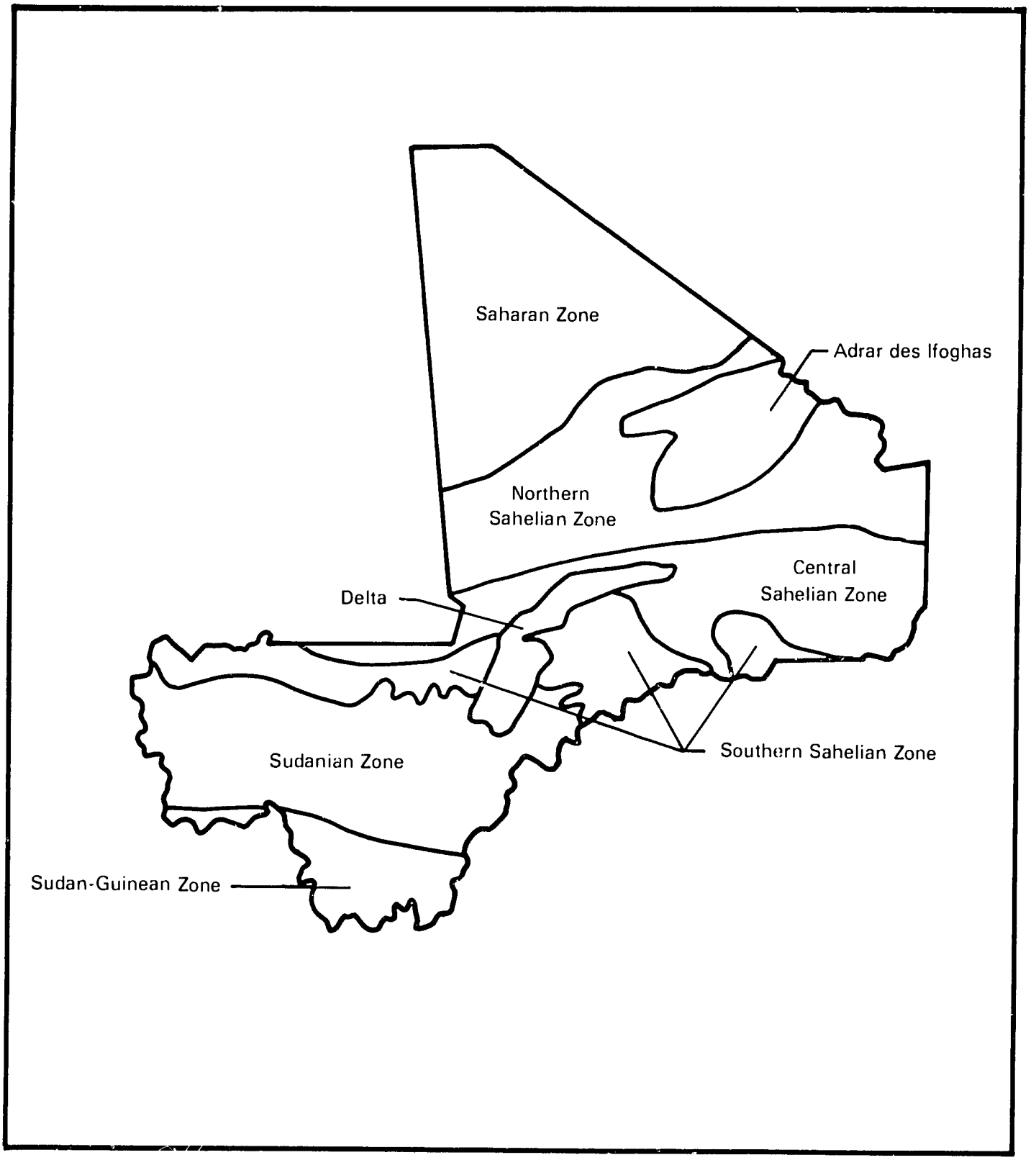
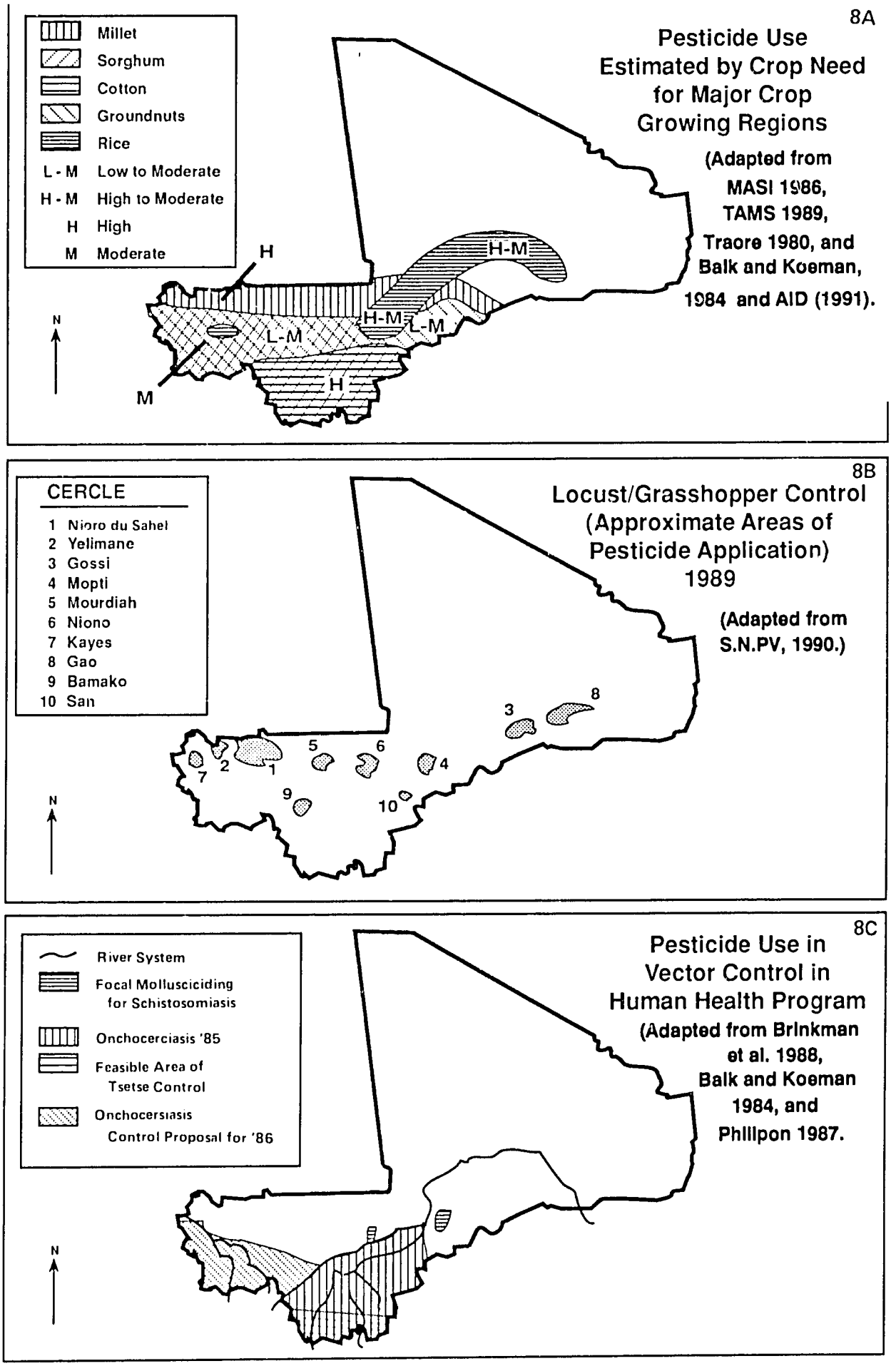


Figure 7. Biotic zones in Mali that may overlap with locust and grasshopper control activities. Adapted from Traore, 1980 and IUCN, 1989.



Peckham, P. 1990 and Peckham, P. and J.C. Cooper, 1991

Figure 8. Additional examples of multiple and overlapping use of pesticides in Mali.

A.I.D. approaches to the locust problem are expected to be beneficial, independent of the locust and grasshopper problems. A major emphasis is on surveillance -- early detection and "low input sustainable agriculture". Detection and control actions that prevent massive populations minimize insecticide use. "Conservative" interventions include "traditional" means of control, setting aside refuges, and establishing buffer zones adjacent to water ways. In addition, A.I.D. will emphasize pesticide safety training and the creation of organizations and infrastructure (e.g., laboratory facilities) that will be useful for other purposes.

4.2 Monitoring, Forecasting and Prevention

As recommended by OTA, TR&D and TAMS, A.I.D. should have an ongoing program that emphasizes systematic monitoring and prevention, integrated into long-term development. Greenness maps technology has been transferred to an AGRHYMET regional center located in Niger. Support should continue for FAO forecasting and prevention programs ("strategic control"). When actual treatments are needed, farmer brigades will be encouraged. Among the specific actions A.I.D. has taken are (1) extending the AELGA project and broadening its scope; (2) budgeting monies for FAO support; and (3) incorporating appropriate language in Supplementary Environmental Assessments for all countries which have, or might have, an active program within the next five years.

Figure 6 illustrates the components of an environmentally sound nationwide program used successfully in China for the past several decades to manage the oriental migratory locusts, *Locusta migratoria migratoria, L.m. tibetensis* (Hsien 1974). After mass spraying of pesticides in the 1950s failed to substantially reduce locust populations, an ecologically-based program was organized.

Through surveys and gathering of ecological information, the points of origin of locust swarms were identified. Thereafter, a variety of methods were integrated to eliminate preferred oviposition sites, and destroy nymphal and adult locusts. Methods to prevent oviposition include tillage to physically destroy eggs, maintenance of water levels high enough to prevent egg-laying habitat, drainage of certain areas to eliminate moisture needed for egg deposition or to desiccate existing eggs, planting of flood-irrigated rice which destroys oviposition sites, redirection of canals and expansion of salt evaporation ponds.

Techniques to suppress nymphal and adult locusts include timed mass transfer and herding of domesticated ducks to consume nymphal locusts, planting of crops and trees unpalatable to locusts, and encouragement of natural enemies such as specific bird species by building artificial nest habitats in grasslands. Spot-treatment with pesticides was used only when necessary.

As the migratory locusts were brought under control, the national network developed to manage locusts was expanded to form the nucleus of an IPM delivery system for other pests.

This innovative ecological approach to locust pest management shows promise for adaptation to grasshoppers and many other pests in many countries, including Africa.

4.3 Effectiveness of Control

A.I.D. should emphasize the effectiveness that control operations have for protection of food sources. IPM should be a cornerstone, and research will continue on economic thresholds. In addition, through the SEAs, A.I.D. should encourage improvements in the data base for crop productivity and crop loss.

Although research on biological control methods has not replaced pesticides, such research should continue. To ensure efficiency in this research, a technical review committee should provide improved oversight and coordination with USDA research on grasshoppers in North America.

Until effective biological control approaches are developed to a more reliable stage, chemical controls may be necessary on occasion. To improve on past performance, A.I.D. should pay close attention to the appropriateness of pesticides formulations and application techniques selected, not only for effectiveness on the target species, but also for minimizing risk to human populations and to non-target species.

Non-emergency (recession period) conditions investing in the creation and maintenance of a pesticide bank is not considered a highest priority right now. This interim period is considered providing a good time to improve the condition of pesticide facilities; A.I.D. is encouraging the upgrading of warehouses and procedures for pesticide handling. For example, A.I.D./Niamey is working with the government of Niger to upgrade the storage conditions for pesticides across the country. A.I.D./W has drafted an up-to-date set of pesticide guidelines for use by missions and governments of developing countries. These guidelines will be completed and distributed in 1991. Among other purposes, the guidelines will serve to apply specifications to A.I.D. purchases of pesticides.

Other aspects of ensuring effective and safe control operations that have been and will continue to be used include: (1) technical assistance in entomology, provided to missions that cannot afford to hire a full-time entomologist; (2) issuing a Pesticide Handbook for Locust Control; (3) providing logistics training in the field; (4) ensuring appropriate use of aerial support; and (5) obtaining inventories of usable pesticides.

4.4 Institution Building and Management Considerations

Institution building and coordination are cornerstones of all A.I.D. efforts. A.I.D.'s locust/grasshopper control program augments efforts of other donors, regional organizations, host governments, and local environmental organizations. For example, in writing the SEAs, A.I.D. supported the formation of local technical committees composed primarily of representatives of various ministries of the host government. Those local committees often did a significant amount of the actual writing and frequently suggested that they continue to work, after completion of the SEA, to ensure that various values (e.g., human health, environmental protection and agricultural production) are incorporated into the decision making process. In many cases, local environmental organizations were also consulted early in the drafting process.

A.I.D. and African countries need to be multidisciplinary and cross-sectoral in approaches to environmental problems. Two ways to achieve this are: personnel in interdisciplinary approaches to problems (i.e., the ability to look at several dimensions of problems); and (2) provide effective mechanisms in government to ensure coordination among different sectors. Research is badly needed in land and water management, pest management and food production and security.

Components of environmental education should be included as appropriate in all activities. This education should include information concerning the environmental implications of actions (completed or pending), training for the types of skills needed to properly evaluate this information (math, science, economics, interpersonal communications, etc.), and exposure to multi-dimensional thinking.

Within countries, the responsibility for environmental policy formulation and management at the national, regional and local levels should be redefined, replacing the accumulated web of overlapping administration and incompletely defined responsibility with an organization that comprehensively administers environmental matters, and which delegates, where appropriate, responsibilities at the regional and local levels. Decentralization,

devolution, and local participation in improved resource management are desirable and commendable goals. It is, however, necessary to be realistic and admit that decentralization will not work everywhere. First, some situations require strong centralized intervention. Second, in many countries the current capacity of local groups to exploit the benefits of this strategy are limited, and training and institution building are required before significant decentralization can take place. Third, key national policies may specifically discourage decentralization and local participation. It is nonetheless important that planners and policy makers encourage local initiative and responsibility whenever realistically possible.

Other institution building and management considerations for A.I.D. include: (1) finding a stable "home" or responsible office for locust/grasshopper control in geographic bureaus (this also benefits integration of locust/grasshopper operations with longer-term development goals); (2) requiring Action Plans as part of approval of locust or grasshopper control activities; (3) staffing to a level appropriate to current problems (with anticipation of long-term needs); and 4) improving computer hardware and software.

4.5 Prevention of Impacts on Health and Environment

A.I.D. must emphasize the prevention of adverse impacts to human health and the environment. A.I.D. staff have assessed control methods and potential impacts. They have field tested pesticides and studied the environmental effects in Mali and Sudan partially supported by international pesticide testing in Senegal, and conducted Supplemental Environmental Assessments in Burkina Faso, Cameroon, Chad, Mali, Mauritania, Niger, Senegal, and Sudan. For the future, A.I.D. may fund a follow-up to the international testing in Senegal and Morocco. A.I.D. intends that the SEAs be dynamic documents, updated at periodic intervals as additional information is available, as new technology in biological control is developed and as policy is refined.

Among the health and environmental emphases in the SEAs are proper applicator training and protection, proper labelling and storage of pesticides, having conservative decision triggers for A.I.D. participation and otherwise encouraging techniques to minimize the area sprayed, insisting on public education in connection with treatment operations including the encouragement of posters in prominent public places, availability of information on symptoms of poisoning and distribution of antidotes, identification and protection of environmentally fragile areas, and identification and disposal of obsolete pesticides and empty containers. In addition, A.I.D. is working with EPA on the development of model container specifications, with other donors and the private sector in establishing improved procurement specifications, with FAO on developing better methods for monitoring impacts on the environment, and with individual countries to validate health monitoring methods using cholinesterase inhibition testing. The emphasis on providing technical assistance should continue. In addition, A.I.D. is working toward privatizing pesticide distribution in a strong regulatory environment, in order to shift the costs to users, thereby decreasing pesticide abuse resulting from high subsidies. Though no comprehensive inventory of uses has been compiled, crops known to have the highest uses of pesticides are the highest priority for this effort.

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