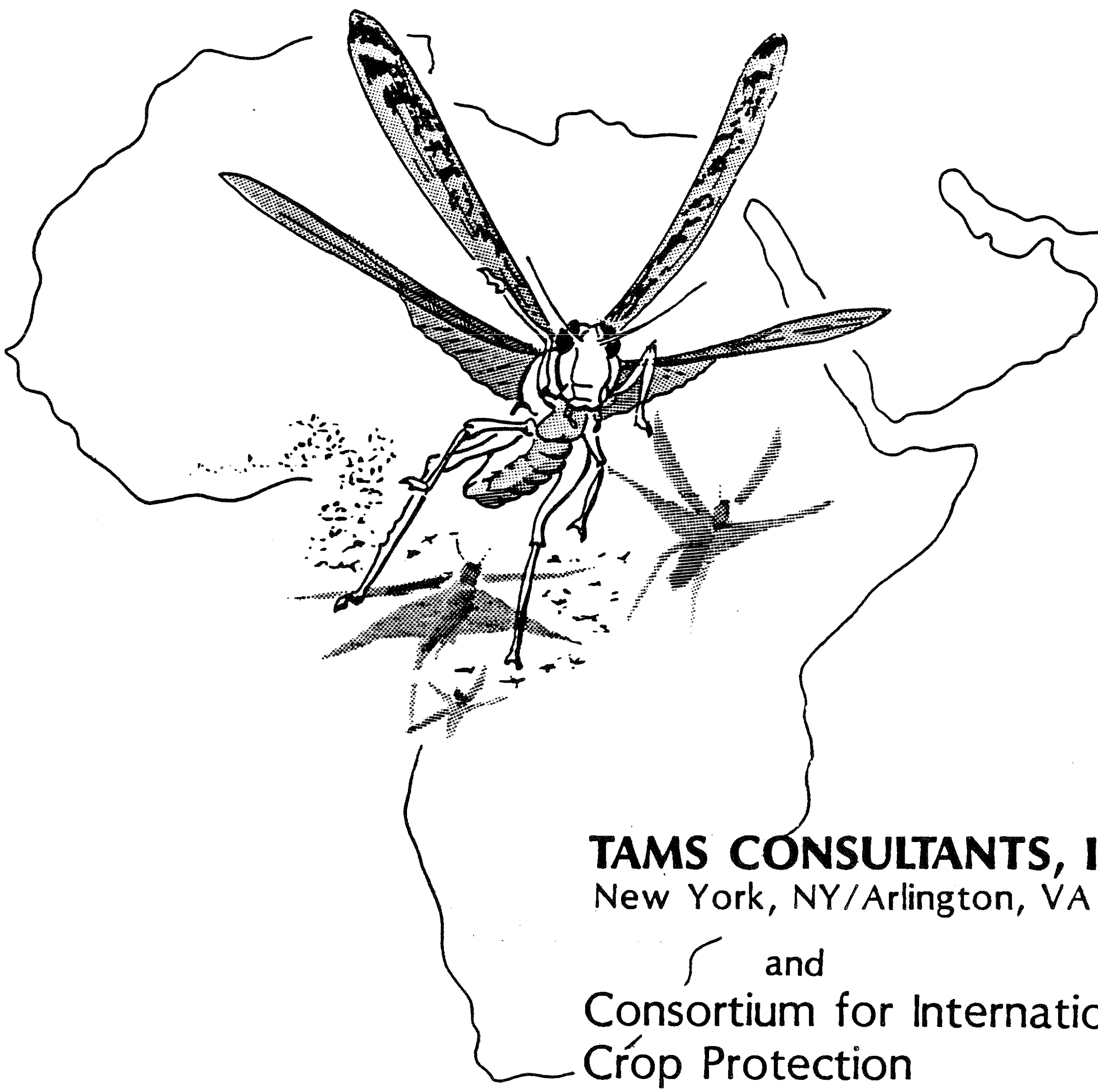
US AGENCY FOR INTERNATIONAL DEVELOPMENT

LOCUST AND GRASSHOPPER CONTROL IN AFRICA / ASIA

A PROGRAMMATIC ENVIRONMENTAL ASSESSMENT



TAMS CONSULTANTS, Inc.
New York, NY/Arlington, VA

and

Consortium for International Crop Protection
College Park, MD

EXECUTIVE SUMMARY AND RECOMMENDATIONS

March, 1989

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A EXECUTIVE SUMMARY

TAMS Consultants, Inc.
2101 Wilson Blvd., Suite 300
Arlington, VA 22201
703/243-8000

and

Consortium for International Crop Protection
4321 Hartwick Rd., Suite 404
College Park, MD 20740
301/454-5147

A. EXECUTIVE SUMMARY

This is a summary of the Programmatic Environmental Assessment (PEA) of locust and grasshopper (l/g) control in Africa and Asia. The detailed PEA is contained in a separate report with appendixes.

A.1 Purpose of the PEA

The purpose of the PEA is threefold:

- firstly, it is to describe the environmental impact of current and projected l/g control programs, with specific reference to pesticide use,
- secondly, it is to evaluate possible alternative control measures and mitigative actions to reduce adverse ecological effects of these measures, and
- thirdly, it is to provide the US Agency for International Development with comprehensive programmatic recommendations which are to ensure that environmental concerns are fully addressed in future l/g control programs.

A.2 Scope of the PEA

The PEA deals with an unusually broad and complex issue. It is concerned with six major locust and three major grasshopper species which affect the environment, crop and range production, in well over 50 nations in Africa and S.W. Asia. It is also concerned with the effects of 13 major insecticides in use or being tested by international organizations, technical assistance institutions of major donor countries, and national plant protection agencies, to control locusts and grasshoppers as well as with the inevitable effect of these insecticides on the environment in Africa and the Near East.

The complexity of this PEA is illustrated by the enormous literature which exists on the biology and ecology of locusts and grasshoppers alone. Over 10,000 acridological abstracts were compiled by the Overseas Development Natural Resources Institute (ODNRI), London. In addition, the Plant Production and Protection Division of FAO also, in 1979, compiled a major bibliography covering 30 years of l/g control activities.

Even though the broad scope of this PEA sets it apart from most routine environmental assessments, it does address the standard EA requirements. The PEA is prepared in accordance with the requirements of 22 CFR 216, "AID Environmental Procedures". The PEA also takes into account AID policy concerns as outlined in Policy Determination PD-6, "Environmental and Natural Resources Aspects of Development Assistance" and the AID Pesticide Policy.

A.3 Selected Locusts and Grasshoppers

Locusts belong to a large group of insects commonly called grasshoppers. Locusts are those grasshoppers which have a capacity for changing their habits and behavior when they occur in large numbers. Locusts may then stay together in swarms and can migrate over great distances.

The Centre for Overseas Pest Research (now ODNRI), in 1982, published "The Locust and Grasshopper Agricultural Manual" which provides excellent descriptions of over 500 different species of locusts and grasshoppers as they occur throughout the world. The majority of these species occur in Africa and South Asia.

For the purpose of the PEA only selected locusts and grasshoppers were taken into consideration. They are listed below:

Locusts and Grasshoppers Selected for the PEA

Common Name	Scientific Name
	LOCUSTS
Desert Locust	*Schistocerca gregaria* (Forskal)
African Migratory Locust	*Locusta migratoria migratorioides* (Reiche & Fairmaire)
Red Locust	*Nomadacris septemfasciata* (Serville)
Brown Locust	*Locustana pardalina* (Walker)
Moroccan Locust	*Dociostaurus maroccanus* (Thunberg)
Tree Locust	*Anacridium melanorhodon* (Walker)
	GRASSHOPPERS
Senegalese Grasshopper	*Oedaleus senegalensis* (Krauss)
Sudan Plague Locust	*Aiolopus simulator* (Walker)
Variegated Grasshopper	*Zonocerus variegatus* (Linnaeus)

The six locust species listed are the dominant locusts of Africa and the Middle East. The distribution of the Desert Locust and the African Migratory Locust is shown in Figures 1 and 2.

The three specific grasshopper species were selected because they act like locusts -- they aggregate and two species can migrate in low flying swarms. They are not just a local problem as is the case with most other grasshoppers, but move

Organization (IRLCO) is active in southern Africa. (See Figure 4.)

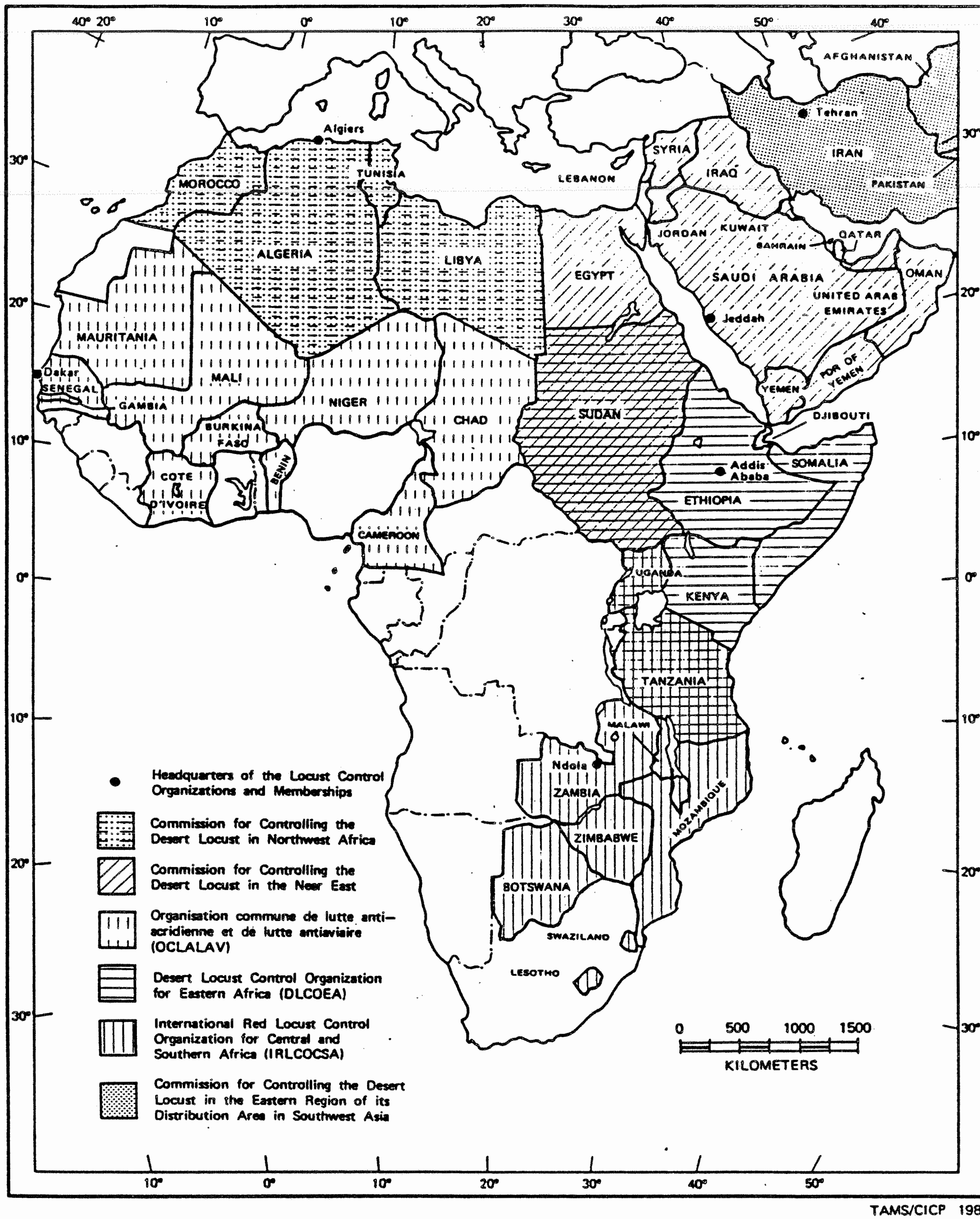

Figure 4. Locust Control Organizations and Memberships
Source: FAO, 1983b

The West African regional organizations OCLALAV and OICMA have not survived the long period since the last major Desert Locust upsurge. Unprepared and largely inadequate national plant protection services had to fill the breach, supported by emergency aid and technical assistance from FAO, AID and other foreign donors. Significant AID contributions have included insecticides, operations and logistics support, locust/grasshopper population and environmental evaluations.

The same organizations fought the major grasshopper upsurge in 1986-87, which seems to have subsided. The cause of the population decline -- whether control operations, weather, natural enemies or all three -- cannot be determined. In general, grasshopper control is relatively unsuccessful. Rather than being regularly suppressed, outbreaks often reach alarming proportions and trigger blanket spraying of hundreds of thousands of hectares.

Forecasting using remote sensing information, predictive population modeling and early warning systems has great potential value for the timely prevention of outbreaks of both locusts and grasshoppers. However, with the exception of an FAO Desert Locust forecasting service, established in 1943, these programs are still in development and only semioperational.

There is almost as little data available on the losses caused by locust and grasshopper control as there is on the cost of their feeding. What is available is donor cost for control programs, particularly for 1986, when there was a major mobilization of donors for the first time in many years. Spending by farmers and local and national authorities is not available for inclusion for most programs.

On the basis of 1986 donor figures control costs were high, with spraying costs of $15-30 per hectare. However, this expense was exceptional, reflecting the need for rapid emergency mobilization and the airfreighting of formulated insecticides from Europe and the U.S.

Without more complete information, the usual economic tools cannot be used to make judgements regarding the costs and benefits of locust and grasshopper control programs. If they are to be continued, more data on costs and pest damage need to be generated.

A.7 Control Techniques and Strategies

Occurrence patterns of locusts are different from those of grasshoppers, and thus control strategies for the two groups of pests differ. Both aerial and ground insecticide application techniques are used, the choice depending on the size and type of the problem.

Grasshopper control efforts aim to protect crops and pasture, and control strategies are based on the biology of the insect and its life stages. The Senegalese Grasshopper, the dominant species in the Sahel, illustrates a general pattern. It is migratory and breeds in range grasses, its favored habitat. As the grasses dry and become less attractive as a food source, these insects move into food crops to feed. The best time for undertaking control operations is at the beginning of the rainy season, with nymphs of the first generation as the target. Populations are generally the most restricted at that time.

Successful grasshopper control depends on efficient surveys to locate and delimit potentially dangerous populations. Unfortunately, affected areas are enormous and efficient survey is lacking in much of Africa.

Locust control strategies are aimed at plague prevention as well as crop protection. Successful plague prevention requires taking advantage of limiting factors in the insects' daily and annual activity cycles.

For example, the most evident limiting factor of the African Migratory Locust in Mali is its movement to the flood plains of the Niger Inland delta at the end of the rainy season after the water has receded. This enables the locust to survive and breed during the dry season when conditions elsewhere are unfavorable. Thus, the most efficient means of control is to reduce or eliminate this dry season population in the hopper stage in the flood plains, before the beginning of the rains.

Strategies can also take advantage of situations in which populations are concentrated. For the Red and Brown Locusts, this means within the outbreak area. For the Desert Locust, this includes terrain features that inhibit migration, such as the northern Ethiopian highlands and the Atlas Mountains of Morocco and Algeria. During the winter months, Desert Locust populations become trapped in a relatively few areas such as these and are then ideal targets for control.

Theoretically, spraying flying locust swarms is highly efficient. In practice, it is usually quite inefficient due to continual expansion and contraction of swarms. The area occupied by gregarious swarming adult locusts when settled is 3 to 10 times less than the area occupied while flying, so wherever possible, control efforts are targeted against settled swarms, to reduce the amount of insecticide and application time required. Control of settled swarms was the strategy used in the successful 1987 Desert Locust campaign in Morocco.

Barrier spraying using a persistent stomach poison is the most efficient method of controlling immature locusts in hopper bands. This technique has worked particularly well in Red Sea coastal areas where as many as six generations of Desert Locusts develop each year. Both aerial and ground ultra-low volume (ULV) application methods can be used. However, with the discontinuance of the persistent chlorinated hydrocarbon insecticides, barrier spraying effectiveness may be reduced.

ULV drift spraying, in which swath displacement by wind is deliberately used to get wider coverage, is commonly used in Africa. With light, steady wind conditions it can cover a larger area within a given time and give better impingement of the spray droplets on sparse vegetation and target insects.

Insecticide baits can be used in both aerial and ground operations, but logistical problems, particularly formulation, transport and storage considerations, limit the situations in which they can be economically used. Baits are safer for applicators and nontarget species, and utilize only a fraction of the amount of active ingredient per unit area that liquid sprays and dusts require.

Properly used ground equipment can give excellent control of grasshoppers and locusts. Operations can be more effective and selective because the applicator sees the actual insects to be targeted, confining the insecticide to smaller areas and thus minimizing nontarget effects. Aerial applicators usually cannot see insects on the ground, and instead spray areas bounded by landmarks which may considerably exceed the zone of actual economic infestation.

Aerial surveys, particularly with helicopters, are useful in detecting flying locust swarms and delimiting grasshopper and locust infestations. Aerial insecticide application is necessary for controlling grasshopper outbreaks that have reached the large scale of the one in the Sahel in 1986-87.

Methods of aerial control are different for grasshoppers and locusts. Grasshoppers must be attacked during the day while they are on the ground, while locusts can be attacked both while they are on the ground or in flight.

In 1986-87, large planes were used in wide scale aerial operations. This was not always necessary or economical and was undesirable from the environmental point of view. Other negative factors were insufficient follow-up, delay between infestation and intervention, and lack of communications and logistics experience.

Separate areas to be treated within one country were sometimes subdivided and parceled out to various donors. This may have had administrative advantages, but aerial spraying on a more rational basis would have been more efficient, would have needed fewer ground teams and would have concentrated efforts when and where most needed.

Despite these problems aerial work was orderly, utilized more highly-skilled people, and was, therefore, able to proceed efficiently. The greater speed and simplicity of aerial spraying allowed ground parties to discover mistakes or failure quickly, so the work could be repeated or improved.

Figure 5 shows the role played by farmers, national crop protection agencies and foreign donors in controlling various types of locust and grasshopper infestation.

A.8 Insecticides

This Environmental Assessment considers thirteen insecticides: the chlorinated hydrocarbons dieldrin and lindane, the organophosphates malathion, diazinon, acephate, fenitrothion and chlorpyrifos, the carbamates carbaryl,propoxur and bendiocarb, and the synthetic pyrethroids lambdacyhalothrin, tralomethrin and cypermethrin. The list includes the seven chemicals that have been used consistently by AID-associated grasshopper and locust control programs: the chlorinated hydrocarbons and malathion, diazinon, fenitrothion, carbaryl and propoxur. The rest are either being tested or used by other international donors. Some new, easier to use combination products are also being developed.

Many of the chemicals are currently registered in the U.S. or Europe for locust and grasshopper control. The registration of one, dieldrin, has been cancelled in most developed countries because of its persistence and bioaccumulation and the resulting negative effect on nontarget species. AID was instrumental in effecting this cancellation.

A.9 Insecticide Use

The selection of an insecticide for use in a grasshopper and locust control program would be simplified if only one chemical was effective, but many, including all those widely used now, give about equally satisfactory control. Selection should be based not only on efficacy but also on persistence, bioaccumulation, toxicity, cost, ease of application and availability.

Because of its harmful effects on nontarget species, dieldrin is unacceptable for use in programs associated with AID. The widespread use of carbaryl, as Sevin 4 oil, is hampered by its initial cost, almost twice that of malathion per hectare treated. A cost comparison of carbaryl versus malathion must consider the effectiveness of these products. Malathion is a quick kill, knockdown product well suited for treatment of flying swarms, and hopper bands on bare desert sand. Due to the short residual of malathion, re-treatment is often necessary. Carbaryl is more suited for crop protection and is properly applied to vegetation or as a barrier treatment involving baits, crop dusting or other types of ground applications. Fenitrothion and diazinon are toxic to birds, and all the insecticides are very toxic to bees and other nontarget Arthropods. Acephate appears to be the most environmentally acceptable insecticide among those considered, but has not been adequately tested against locusts and grasshoppers in Africa and the Middle East.

FIGURE 5. LOCUST AND GRASSHOPPER CONTROL

L/G GROUPS	Ground Control		Aerial Control
	Farmers	CPA	CPA & Donor Suppo
Locusts			
- Solitary	1)	1)	1)
- Hopper Bands		S	S
- Flying Swarms			S
- Settled Swarms		S	S
Specific Grasshoppers 2)			
- Solitary	A	A	
- Flying Swarms			3)
- Settled Swarms		S	S
All Other Grasshoppers	A	A	

1) no control necessary since not present in farmland
2) the three grasshopper species treated in this report
3) swarms fly at night, air control not feasible

CPA: Crop Protection Agencies
A: annual control
S: control in some years only

The requirements for insecticide formulations for grasshopper and locust control are that they must be applicable by well-tried methods, be noncorrosive and non-phytotoxic, and storable for at least 18 months and preferably up to 5 years. Persistence also is important. Fast-acting contact insecticides are effective for spraying swarms of adult locusts, but in many other situations residual toxicity is a valuable characteristic. Cumulative stomach poisons that are not easily excreted or detoxified are efficient because insects that first receive a sublethal dose can ingest lethal amounts as they move about in their search for food. Dieldrin and lindane are the most persistant of the insecticides considered.

None of the insecticides considered are very selective, i.e., more harmful to the target pests than to nontarget species. Maximum selectivity is environmentally desirable, and there is an effort to use formulations such as baits in a selective manner: directed as narrowly as possible during selective times at the target insects, minimizing the areas and other species affected.

A.10 Insecticide Management

It would be economic for locust and grasshopper pesticides to be formulated in or near the African or Middle Eastern countries where they are used. In 1986, the expensive emergency airlift of formulated insecticides from developed countries inflated control costs. Dusts were particularly wasteful, since they are only 1-2% active ingredient, with the transport cost of the dusts greatly exceeding their insecticidal value.

Storage facilities have been identified as an acute problem. Many pesticides are stored in unfenced areas in the open, often adjacent to populated areas. Where there are stores, they are often poorly ventilated, in disrepair, and badly managed.

In addition to poor storage, inappropriate container size for the intended end user and containers that are not sufficiently durable for transportation create hazardous situations.

The disposal of containers is a problem because people often want to recycle them and use them for water and food.

A.11 Insecticide Disposal

When insecticides are prepositioned for grasshopper or locust problems which fail to materialize as anticipated for long periods, they must be used for another appropriate purpose or be disposed of once they become outdated. For example, some chemicals supplied by donors in 1987 are still stored and may not be useable by farmers.

Another disposal problem is posed by large remaining stocks of chlorinated hydrocarbon insecticides in countries such as Yemen, Somalia, Sudan and Mauritania. Some of them have been stored since the early '60s. They are no longer approved for application, and so cannot simply be used up.

A.12 Health and Safety

The general public may be exposed to insecticides through water or food that has been contaminated, through spills or drift, and overspraying of the water supply or food crops. Those handling, mixing, loading, or applying the chemicals receive the heaviest exposure and are the group for which protection and health monitoring is the most critical. Protection includes both protective clothing and devices and adequate training in safe handling and use of pesticides.

For the public, assessment of exposure is through the determination of residues in environmental samples such as water, air and food supplies, human fat and milk.

In large control programs, emergencies inevitably occur. Of immediate concern are emergencies that occur in transport, storage, use or disposal of the chemicals. These include leakage, spills, splashes or drift, with resulting contamination of humans, the water supply or food crops and the creation of hazards for beneficial nontarget organisms.

A.13 Training

During a workshop held for AID participants and consultants in the 1985-87 locust and grasshopper control progams, the continuing need for training was emphasized. More than 50 current issues in the campaign were identified as subject matter. In most countries and regional organizations, experienced locust officers decreased in number during the long recession, and the present upsurges offer an opportunity to train a new generation.

For field staff and farmers, concentration should be on short, practical, hands-on courses. During the spring of 1987, AID successfully conducted Training-of-Trainers courses for personnel who handle and apply pesticides.

Among high-priority training topics for officers are the logistics of large-scale operations, radio operations and maintenance, and aerial spraying techniques. Aerial operations require well-trained pilots and support staff. More African pilots need to be trained, and refresher courses are required for those currently available. There is also an urgent need to train personnel in insecticide storage, calibration of equipment, and transport facilities. Stores construction, the logistics of distribution, and the administration and management of stores are all important.

Safety training is essential for all persons who come in contact with insecticides: topics include safe handling, the use of protective clothing, safety precautions in mixing and filling tanks, and cleanup procedures. Field workers should know to delay entry to the sprayed field for a safe period, and to avoid drift.

A.14 Control Methods Other Than Broad-Spectrum Insecticide Use

At present, there are mechanical and cultural methods available for locust and grasshopper control: collecting and killing the insects, upgrading pasture and trying to alter the environment in ways unfavorable to the pests, and the destruction of eggs in oviposition fields. None of these methods is immediately effective, applicable to a broad range of species and practical or even feasible in most situations.

Biological control, particularly the use of pathogens, might hold promise for the future. At present, neither predators, parasites nor pathogens are being used in Africa and the Middle East for locust or grasshopper control, nor have any been sufficiently tested to prove their value. Antifeedants, particularly Neem extracts, may become useful for crop protection. The feasibility of Neem insecticide manufacturing as a Sahel village industry is being investigated. Some crop varieties have antifeedant characteristics, but this is not being exploited outside the traditional context.

A.15 The Environment

The combined recession and invasion areas of the nine species of locusts and grasshoppers described in the project covers virtually all of Africa and the Middle East. Africa, with its wide range of climatic zones, combined with its varied topography, has environments that range from deserts to humid tropical rain forests to frost- and snow-affected highlands.

The Middle East is dominated by desert and arid environments but also includes moist sub-humid, Mediterranean and mountain climates.

Within the more arid zones, temperature and rainfall are major factors in the hatching and growth of locust and grasshopper populations. In these zones, the variability in rainfall between years has also been suggested as a key factor in plagues -- wet years as breeding times for locusts and long periods of drought leading to reductions in populations of locusts, although populations regain quickly when rain returns.

The intertropical convergence (ITC) zone, moving from the Equator in the winter to the Sahara in the summer, is another climatic phenomenon important to development and migration. The ITC promulgates weather fronts and rain associated with grasshopper and locust breeding areas, and also creates wind patterns that govern the movement and orientation of locusts and grasshoppers in flight.

Rainfall provides the soil moisture that leads to locust and grasshopper hatching, as well as to crop and vegetation growth. In Africa, at the scale of this study, ten major soils associations are distinguished, namely: desert soils, sandy soils, saline soils, acid soils of tropical lowlands, soils of tropical highlands, dark clay soils, ferruginous tropical soils, Mediterranean soils, poorly drained soils and shallow soils.

In the Middle East soils have been distinguished for the true deserts, the arid steppes, the sub-arid and sub-humid areas.

The distribution of the major soil associations broadly corresponds with the climatic zones and vegetation types. The major vegetation types of Africa range from humid rain forests to deserts, with a wide variety of thickets, wetlands, savannas, grasslands, altitudinal and edaphic types in between. In the Middle East the main vegetation types are Mediterranean, steppe, desert, mountain, savanna and riverine vegetation. The natural vegetation provides food, fiber and fuelwood for man, forage for man's domestic stock, and food and habitat for Africa's and the Middle East's varied and important wildlife resources, including locusts and grasshoppers.

The importance of wildlife includes, but is not limited to, contributing significantly to the protein portion of some local diets, maintaining ecological stability by being better adapted than domestic livestock to the local environment, and providing, or having the potential to provide, an important foreign exchange revenue from national park and wildlife-based tourism.

In both Africa and the Middle East, shrinking forested lands, and more importantly, the rapid decline in woodland edge areas, have caused declines in several forms of plants and wildlife.

The surface hydrology of the African continent is dominated by four major river basins: the Nile, the Zaire, the Niger and the Zambezi. Major natural and dammed lakes include Lake Chad, Lake Volta, Lake Nasser, Lake Victoria and the Rift Valley lakes. These and other African lakes and rivers are associated with extensive wetlands in the form of flood plains, swamps and smaller lakes, all of which are considered critical habitats that support a diverse fauna, fisheries and a growing number of aquaculture activities.

Groundwater is a secondary source of water in Africa that comprises some 20% of the total water resources of the Continent.

The main surface water in the Middle East is represented by the Tigris and Euphrates Rivers in Iraq and the Caspian Sea bordering the study area. Several moderate size lakes, mostly saline, are found in Iran.

Within the varied African and Middle Eastern environment described above are several geographic features that preserved barriers to or otherwise affect the movement of grasshoppers and locusts. In Africa, these include the Atlas Mountains of Morocco, the Piedmont Atlas of Algeria, the mountains of northeastern Somalia, and the Ethiopian highlands. Locust movement is modified in the Middle East by the Saudi Arabian escarpment, the mountains of Yemen and Hadramaunt and the northern mountains of Iran. Surprisingly, the Sahara, Arabian, and Pakistan deserts appear to be no impediment to locust movement.

The human settlement patterns in Africa are characterized by rural-urban migrations, migrations into new areas of agricultural development, the movements of traditional nomads, migrant labor forces and the locations of traditional village communities. Heavy population concentrations are found along most of the river valleys, along the coast and in high plateaus of Ethiopia, Kenya, Burundi and Uganda and in Nigeria. Sahelian regions are less populated.

In the Middle East as in Africa, there are both sedentary and migratory populations. Higher population densities are found along the shores of the Mediterranean Sea, the Caspian Sea, and in the Fertile Crescent.

A number of major international efforts that deal with public health problems caused by tropical diseases also depend upon projects in which pesticides are used. Inevitably, the use of pesticides for the control of human disease of public health importance overlaps with similar applications for agricultural pests. Unfortunately, many locust and grasshopper programs that use pesticides occur in rural areas with limited health services, and adequate personnel are seldom available to document or assist with health problems that may arise there.

A.16 Environmental Consequences of Pesticides Used

The environmental consequences of pesticide use discussed for the terrestrial and aquatic environment and for human health, are based on three subassessments:

- o hazard analysis (toxic properties of each insecticide)
- o exposure analysis (likelihood of exposure to non-target organisms)
- o risk analysis (effect of insecticides on non-target organisms).

Locusts and grasshoppers follow green vegetation. Animals associated with these areas -- either through feeding on locusts or by using the same ecological resources -- can be exposed to pesticide spray operations. Exposure can occur dermally (directly or from sprayed vegetation), by inhalation of spray, or through ingestion (eating contaminated species, preening by mammals and birds).

The soil fauna, including millepedes, mites, spiders, and insects, is important to the maintenance of soil fertility. Loss of many of these organisms alters soil characteristics such as internal drainage.

Soil type, climate and type of pesticide applied all influence the persistence of chemicals in soils, and thus the long term detrimental affects. Chlorinated hydrocarbons are highly persistent, while organophosphorous insecticides are mineralized in several weeks. Chlorinated pesticides also demonstrate limited mobility in soils, which means that they tend to remain on or near the surface and can run off to aquatic environments, where they present continued hazards to non-target organisms. Other insecticides are more readily leached into lower soil horizons. The characteristics of lower persistence and mobility in soils suggest that non-chlorinated pesticides may have fewer long-term detrimental affects on non-target organisms than do chlorinated hydrocarbons.

Much of Africa is characterized as having degraded soils, which are overcultivated and exhibit erosion, loss of topsoil, and soil crusting (which increases runoff). Removal of vegetation for fuelwood may accelerate leaching. These poor soil conditions greatly increase the detrimental consequences of pesticides on non-target organisms and systems, thus influencing the overall potential hazards of spray applications.

Most of the pesticides under consideration have little or no phytotoxic effect on vegetation when used in recommended dosages. However, fenitrothion ULV causes severe phytotoxicity in sorghum.

Toxicity ranges on terrestrial organisms for pesticides considered for locust and grasshopper control range from moderately toxic to mammals (malathion) to highly toxic to birds (fenitrothion), to slightly toxic to birds (carbaryl), to highly toxic to bees and other associated invertebrates. Chlorinated hydrocarbons are generally highly toxic to all non-target organisms.

Organophosphates adversely affect non-target terrestrial organisms. Fenitrothion and diazinon kill significant numbers of birds in laboratory studies and in field applications, while carbaryl and malathion are without observed effects. Carbaryl is toxic to a broad range of non-target invertebrates. Malathion is toxic to some birds. Lindane is toxic to fish and birds but not very toxic to mammals.

It is now accepted widely that use and registration of pesticides for locust and grasshopper control should be limited to those that have the least direct effect on non-target wildlife, that degrade rapidly in the environment and that have been thoroughly tested in the field as well as in the laboratory. Chlorinated hydrocarbons do not meet those criteria. Fenitrothion, due to its high toxicity to birds, must be used with caution. Figure 6 summarizes the overall effects of all 13 pesticides on non-target organisms.

Pesticide use near concentrations of birds feeding on locusts and grasshoppers, during bird migrations, in bird breeding and nesting sites, and near critical habitats needs to be examined further to ascertain both short- and long-term affects of pesticide applications. Potential consequences for such concentrations of birds are discussed.

The toxicity of the 13 pesticides considered (see Figure 6) varies from nil to severe on fish and aquatic invertebrates. Pesticides that are inadvertently sprayed directly on water bodies are expected to have effects on aquatic organisms. In most cases aquatic invertebrates will be killed, but overall effects on organisms in streams and rivers can be expected to be temporary, since those can be repopulated from other areas. By use of buffer zones, selective use of the least harmful pesticides, and careful application, fisheries resources can be protected.

Acephate, propoxur, carbaryl, fenitrothion and malathion are less toxic to fish than are synthetic pyrethroids (lambda-cyhalothrin, tralomethrin and cypermethrion and dieldrin). Diazinon, lindane, bendiocarb, and chlorpyrifos are of intermediate toxicity.

Toxicity to aquatic invertebrates is considerably different. Here, the three pyrethroids (lambda-cyhalothrin, tralomethrin, and cypermethrin), fenitrothion, diazinon, propoxur, and chlorpyrifos are of high toxicity; malathion, carbaryl and acephate are of low toxicity, with lindane and dieldrin of intermediate toxicity.

A risk analysis for the aquatic environment was computed by comparing the expected exposure to potential hazard (toxicity, etc.) to the species. Pesticides that appear to allow little or no safety margin in toxicity to fish (and which therefore will cause detrimental effects) include lindane, chlorpyrifos, diazinon, malathion and the three synthetic pyrethroids. Acephate, propoxur, carbaryl and bendiocarb appear

FIGURE 6. TOXICITY TO NON-TARGET ORGANISMS

Chemical	Persistence	Bioaccumulation	Birds	Mammals	Fish	Aquatic Invertebrates
carbaryl	L	L-M	L	L	L	L
diazinon	M	M	M-H	L	M	H
dieldrin	H	H	H	H	H	M
fenitrothion	L	M	H	L	L	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*		L	H	H
lambda-cyhalothrin	M	H*	L	H	H	H
tralomethrin	M	H*	L	L	H	H

*based on log P

to have a sufficient safety margin. Dieldrin which appears to have a sufficient safety margin, is not acceptable because of high persistence and high bio-accumulation potential. Fenitrothion appears to be relatively non-toxic for fish, but is extremely toxic to invertebrates and aquatic birds and should be used with caution.

The persistence of the pesticides in aquatic systems varies from low (malathion, carbaryl, fenitrothion) through moderate (diazinon, bendiocarb, propoxur) to high (lindane, chlorpyrifos, dieldrin). Pesticides with higher persistence have a greater potential for environmental damage, as well as in food-chain transport or bioaccumulation. There are a wide range of risks to human populations, including occupational, accidental and subliminal. Pesticide workers have the highest exposure. Others are exposed through dermal exposure and ingestion. Several health conditions occur from various levels of exposure to pesticides, including skin abrasions, malnutrition, liver disease, respiratory infections, and eye infections.

A.17 Wilderness Areas

A recent inventory of Africa indicates that 30% of the continent is comprised of wilderness areas (see Figure 7). Of these, 7% has been set aside as protected for the conservation of these resources. These areas contain critical habitats, and are designed to protect wildlife comprised of numerous species. A buffer strip of 5 km, in which no chemical spraying is allowed, is needed to protect these areas.

Many wetlands are significant and are considered critical habitats. Like other critical habitats, these wetlands receive pesticides through aerial drift from spraying. Buffers of 5 km for the borders and 16 km for the areas constituting the origin and its defined outlets are recommended to protect these wetlands.

These buffer zones above, are the ideal. For practical purposes a reduced buffer zone, 2.5 km, is recommended as a first step, with the intention that in the future, wider zones can be put into force.

A.18 Rare and Endangered Species

To protect rare and endangered species, compliance with existing regulations and standards should be followed and should include:

1) follow EPA label guidelines,
2) avoid applications on specific grasshopper and locust sites where listed species are known to exist, and
3) prohibit use of those chemicals that would result in direct or indirect harm or mortality for listed species.

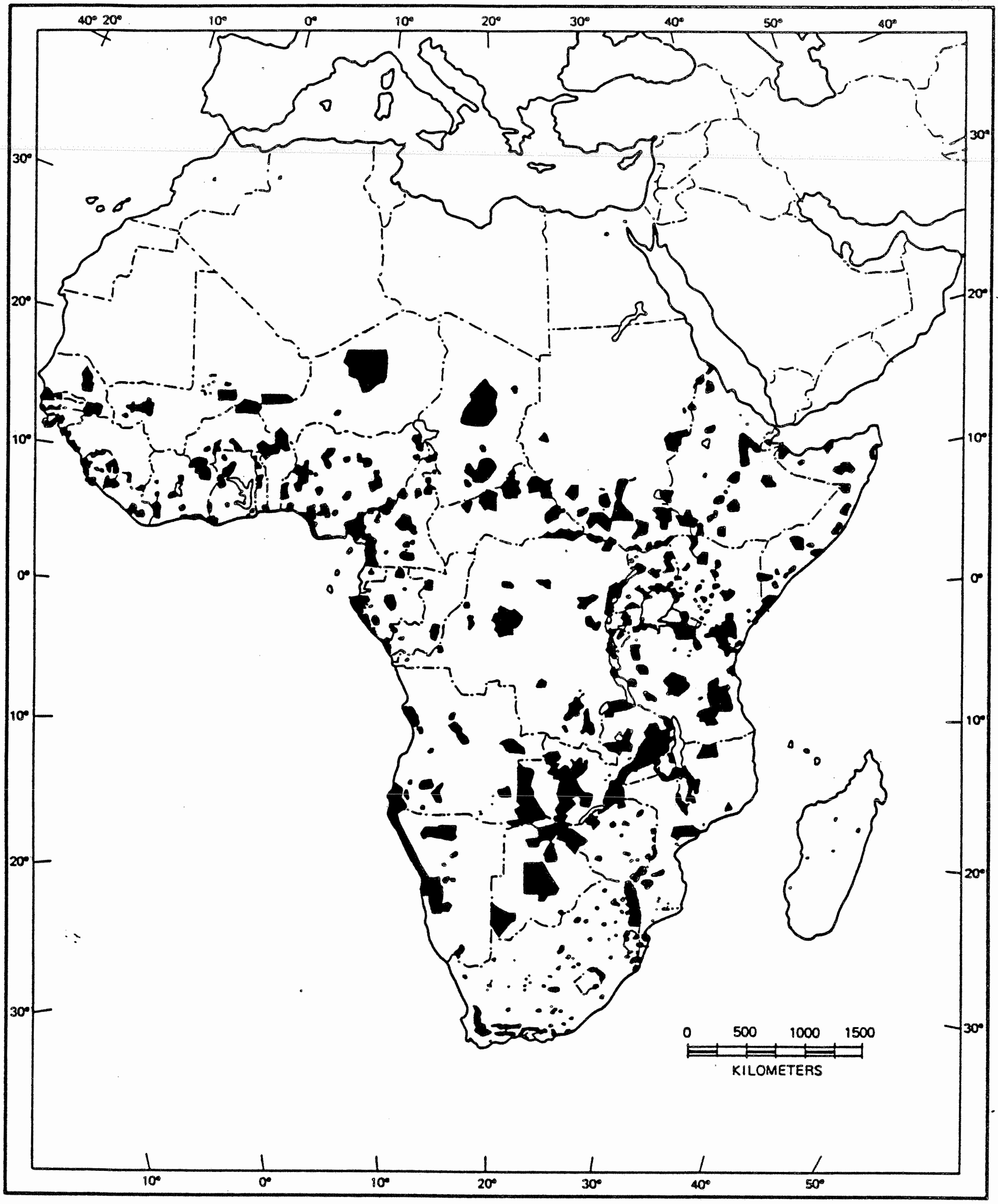

Figure 7. Protected Area in Africa. The degree of protection afforded to each of the areas is not shown.
Source: International Wilderness Leadership Foundation (undated)

A.19 Areas of Overlap

There are areas of direct overlap between environmentally sensitive and critical habitats, and locust and grasshopper control regions. A thorough inventory of these areas is needed to more precisely estimate the degree of overlap and the extent of the problem. These areas include semi-arid regions, temperate lands and marshes, seasonal (rainfed) cropland, rivers and permanent lakes and marshes, and protected areas.

A.20 Technical Alternatives for L/G Control

Five technical alternatives are considered. These are:

- No control alternative
- Non-chemical control alternative
- Biological control alternative
- Chemical control alternative
- Integrated Pest Management (IPM) alternative.

The fourth of these measures -- chemical control -- is the one in use at present, with the other control measures being examined as potential alternatives.

A.21 No Control Alternative

This is essentially what was happening prior to the advent of chemical controls. It would involve allowing grasshopper and locust outbreaks to run their course. The consequence of this depends in part on what is being achieved at present. If present control measures merely protect standing crops, the effect of "no action" would be to lose some part of those standing crops. In 1986, the effect of not controlling the grasshopper outbreak in Africa would have been the loss of crops valued at around $M77. With control measures, some $M46 of this potential loss was saved, but at a cost to donors of $M40. However, if the effect of control measures is to control plagues, then the saving in crops was not just in 1986 but in 1987 and onwards as well. It is not clear from the conflicting evidence whether, in fact, existing control measures prevent plagues. It should, however, be borne in mind that even without control measures, plagues will terminate. Between 1860 to 1976 there were 40 identified regional Desert Locust plagues. In all but four cases control was non-existent or completely inadequate, but all of them came to an end.

The environmental consequences of no control would be to reduce the pesticide being applied, with a consequent reduction in any harmful effects of that application. There would, of course, be more grasshoppers and locusts, and this would mean more vegetation eaten. However, there is no evidence that this would be permanently harmful to the forest, bush and rangeland, which has historically been subject to such outbreaks.

A.22 Non-chemical Control Alternative

This involves mechanical methods of destruction, changes in cultural practices in agriculture and/or the use of seed extract of the Neem tree (Azadirachta indica) as an anti-feedant. Mechanical destruction of locust and grasshopper eggs probably has some local impact but has no impact on the larger population. The use of Neem as an anti-feedant is similar, in that by spraying it on a crop, the locusts or grasshoppers are encouraged to move elsewhere, but to have an impact on a national scale would involve spraying much, if not all, of the cropland in a country, which would almost certainly be more costly than spraying of swarms of locusts with pesticides. Overall, non-chemical control measures cannot successfully be used on their own to control locust outbreaks, although they might usefully be employed in concert with chemical control measures.

A.23 Biological Control Alternative

This is really an idea whose time has not yet come. Superficially attractive, biological control would have little or no adverse environmental impact but would control locust and grasshopper outbreaks. At present, the only means by which it might do this is by use of the protozoan organism Nosema, which is licensed for use in the US. The problem with Nosema is that it has not been shown to control grasshopper outbreaks. To date, no field trials have been carried out to test its efficacy in Africa or Asia, where it might work better than in the US. However, even if it proves effective in killing locusts and grasshoppers, there are problems in utilizing it in a control program. Storage needs for Nosema are exacting, with precise temperature control required, and timing of the application critical. In Africa and many of the other countries where locust and grasshopper control programs are in place, such requirements might make Nosema a less attractive alternative to chemical control even if it proved to be efficacious.

A.24 Chemical Control Alternative

This is the only one of the technical alternatives that is proven. There can be debate as to whether its use merely protects the standing crops or whether it prevents locust and grasshopper plagues, but there is no doubt that most of the pesticides in use in locust and grasshopper control programs kill the target species. From the environmental standpoint the problem is that they also kill non-target species. The other problem with chemical control is cost. In 1986 it was costing between $15-$30 per hectare to spray against grasshopper in Africa. In part this was the result of the fast mobilization of donors in response to a perceived emergency, followed by a massive spraying campaign. In the past, locusts and grasshoppers have been controlled with much lower costs. Selective spraying has made chemical control not just an effective means of controlling the pest, but a cost-effective means of control. Selective spraying, as compared to widespread spraying of vast areas, also reduces the potential environmental hazard, but there is a definite overlap between control areas and environmentally fragile areas, and this problem must be addressed.

Selective spraying, in part, is dependent upon early identification of locust and grasshopper breeding and outbreak areas. Forecasting and early warning can be of great assistance in pinpointing these areas. Present advances in using remote sensing have a large potential contribution to make in this area. The FAO's ARTEMIS system is being developed to maximize the use of such integrated remote sensing information processing techniques and the US's EROS Data Center recently completed a pilot grasshopper remote sensing early warning project in Senegal and Mauritania, using somewhat similar methods.

A.25 Integrated Pest Management Alternative

IPM involves a judicious mixture of control methods, including chemical controls. At this time, with chemical control as the only effective means of dealing with locusts and grasshoppers, an IPM approach reduces to the judicious use of chemicals with a willingness to utilize other control methods should they become available. In terms of field operations it amounts to good, careful chemical control.

The technical alternatives are theoretical rather than actual. There are, at the present time, only two alternatives -- that of taking no action, or of mounting a control effort using chemical control. If control is chosen, then the technical alternatives really come down to different approaches within the chemical control operation: either that of large scale spraying of extensive areas, as was adopted in 1986, or more selective spraying of carefully targeted outbreak areas. The latter presents less potentially harmful environmental consequences, as well as being the more cost-effective approach.

A.26 Options for AID L/G Policy

The policy options for AID are reduced in essence, to three. These are:

- to take no action, leaving l/g control to other organizations,
- to take no action on l/g control but to provide food aid to replace the crops lost to locusts and grasshoppers; or
- to continue to play an active role in l/g control.

A.27 No Action by AID

To take no action would have a twofold advantage. By moving out of the l/g control field, AID funds become available for allocation to other programs, programs that, in many cases, are going to show much higher rates of return. Also, AID moves out of an area that, because it involves the application of pesticides, has adverse environmental effects.

The disadvantages are that this would involve AID turning its back on a situation which, from time to time, becomes an emergency. From the environmental point of view, a decision by AID not to remain involved with l/g control would be unfortunate. AID has, for many years, been one of the most responsible voices with regard to environmental impacts of pesticides. If it was to withdraw from the program, that voice would carry considerably less weight.

A.28 Provision of Food Assistance

The option of taking no action but providing food assistance would appear to suffer from most of the disadvantages outlined above, with the further difficulty of having to try to determine crop losses due to locusts and then handling the problems of food distribution. The advantages are that, from the US point of view, food aid can be thought of as fairly cost-effective. From the host country point of view, however, it can be seen as an encouragement to depend on US food assistance rather than deal with the locust problem.

A.29 Intervention in L/G Control by AID

The present strategy followed by AID is to intervene in l/g control. This has the disadvantage of being involved in a program that frequently does not look cost-effective, and one that has some possible adverse impact on the environment.

On the plus side, AID has been actively involved in a situation that appeared to require prompt and adequate emergency response and this has been good for the Agency's image and for that of the US. The Agency has exercised a leadership role in the area of responsible use of pesticides where the US has taken the lead in trying to reduce the use of the more toxic chemicals.

However, if AID is to remain involved in l/g control some changes in approach are required.

A.30 Longer Term Perspective

The present situation, that of dealing with locusts on an intermittent, emergency basis is the worst of all worlds. There is little or no structure in place in many of the African countries, so that when an emergency situation occurs there is very limited ability to mobilize local technical and logistical support; formulated chemicals, equipment and technical personnel all have to be brought in, making the operations very costly.

Clearly, a better situation would be one in which there was a crop protection organization in country, staffed, equipped and ready to mobilize against locust outbreaks. An approach that seeks to achieve this and to make each country more responsible for, and better able to deal with, its own locust problems would appear to be a desirable objective. The problem with trying to achieve this is that locust and grasshopper outbreaks are intermittent. Therefore, the cost of the effort, relative to the benefits, is unfavorable. An organization that sits waiting -- maybe 5 or 10 years -- for a locust plague to surface is likely to become bureaucratic and operationally ineffective; plus, pesticides have a limited shelf life and so will need to be destroyed and replaced every couple of years.

All this argues that, in order to achieve l/g control, the best approach is within the context of a broad pest control program within each country rather than a specific locust control program. The advantages of making the program broadly based are that the benefits relative to the costs of the program immediately look a lot better, and the organization is constantly in the operational mode, with little problem in adapting to deal with locusts, grasshoppers, army worms or whatever other pest requires a major control effort.

From the AID point of view, such a strategy involves a long-term programmatic approach to the problems of locust and grasshopper control with the eventual two-fold objective of controlling all locust and grasshopper outbreaks before they ever approach plague proportion and, in the long term, leaving this control in the hands of the crop protection services of the host countries themselves, with little or no need for donor assistance.

B. PROGRAMMATIC RECOMMENDATIONS

A total of 38 Recommendations were developed as a result of the Programmatic Environmental Assessment (PEA) of locust and grasshopper control in Africa and Asia. These Recommendations are presented here and are divided into Sections I through VI in order of priority. No priority is set within each Section where Recommendations are grouped by topic.

Section I contains one Recommendation only, which is considered a pre-condition for all of the others.

Section II contains Recommendations 2 through 11 which have top priority and should be implemented immediately. (Due to the difficulty of carrying out Recommendation 8 under field and laboratory conditions, delays in full implementation are to be expected.)

Section III contains Recommendations 12 through 26 which focus on locust/grasshopper control actions, where implementation is a high priority, and which should be implemented as soon as resources can be allocated.

Section IV contains Recommendations 27 through 30 which involve a broader scope of involvement and benefits within the agricultural and environmental fields, where implementation is a high priority and which should be implemented as soon as resources can be allocated.

Section V contains Recommendations 31 through 36 which are desirable but of a lower priority.

Section VI contains two final Recommendations, 37 and 38, designed to enhance and accelerate the implementation of the Recommendations of Sections I - V.

Some of the Recommendations are closely related, but are separated by Section. This was done to establish an initial order of relative concern or importance. This document is dated and as experience is gained these Recommendations should be refined. Also, in relation to future conditions and resources, the actual priorities may need to be readjusted and in some cases related Recommendations could best be combined.

SECTION I

Recommendation 1

It is recommended that AID continue its involvement in Locust and Grasshopper Control. Operationally, the approach to be adopted should evolve toward one of Integrated Pest Management (IPM).

This involvement should not be on an emergency basis, but a long-term commitment with the objective of building up the crop protection services of the host countries so that eventually they are able to assume full responsibility for locust control. Operationally the approach to be adopted should be one of Integrated Pest Management. It needs to be emphasized that the only (presently available) way of controlling significant outbreaks of locusts and grasshoppers is the use of chemical insecticides. Therefore, the use of present methods would continue, but with the application of mitigative measures to minimize adverse insecticide impacts on public health, livestock, and the environment. Also commitment is required to adopt effective and economical non-chemical methods that may become available in the future.

SECTION II

There is an immediate need, at the present timeto take stock of the situation in the field. Recommendations 2, 3, and 4 address this issue. All Recommendations in this Section have top priority and should be implemented without delay.

INVENTORY AND MAPPING PROCEDURES

Recommendation 2 — It is recommended that an inventory and mapping program be started to determine the extent and boundaries of environmentally fragile areas.

From an environmental standpoint this is the most urgent need. These would be areas containing wildlife species of particular concern, national parks, forest resources, wetlands and other fragile areas.

This program requires the development of standardized criteria for and the implementation of a systematic assessment of existing data. The review needs to be done on a country by country basis primarily through research with resource management and other appropriate agencies and in line with established international conventions. The end product, maps, needs to be dynamic, that is, take into consideration seasonal fluctuations, of wetlands and non-target species.

Only when this review has been done, can Recommendation 6, regarding areas that should be protected from pesticide application be implemented effectively.

Such a program will, of course, be of use outside of the rather narrow confines of locust and grasshopper control. It will be a resource that can be utilized to address the environmental consequences of a wide range of projects in the countries involved.

Recommendation 3 — It is recommended that a system for dynamic inventory of pesticide chemical stocks be developed.

There are at present stocks of obsolete pesticides from previous locust and grasshopper (as well as other) campaigns in many of the countries of Africa. These stocks can pose serious environmental problems.

The proposed system should look at methods of inventorying existing stocks of pesticides, existing storage facilities, disposal facilities, disposal procedures and laws, and chemical accounting procedures.

Recommendation 4 — **It is recommended that AID take an active role in assisting host countries in identifying alternate use or disposal of pesticide stocks. Refer to Recommendation 14.**

Recommendation 5 — **It is recommended that FAO, as lead agency for migratory pest control, be requested to establish a system for the inventory of manpower, procedures and equipment.**

This inventory system would list the: available equipment in terms of planes, spraying equipment, vehicles, and their operating condition; available trained manpower including technicians, chemists and environmental scientists; the present environmental and public health monitoring procedures; and state of the existing crop protection service. This information is necessary before Recommendations 9, 10, 11, and 32 can be usefully implemented.

Recommendations 2, 3 and 4 can commence at the same time. It is recognized that to try to implement these Recommendations across the board, in all countries where AID is involved in locust and grasshopper control, would be an impossible task. Therefore it should be commenced as soon as possible, on a pilot basis, in one or two priority countries.

MITIGATION OF NON-TARGET PESTICIDE EFFECTS

Recommendation 6 — **It is recommended that there be no pesticide application in environmentally fragile areas and human settlements.**

Buffer zones of 2.5 km should be established around water bodies and buffer zones of 2.5 km established around human settlements and areas containing endangered species or in critical habitats. The season or even time of day can be important in determining the feasibility of treating critical habitats.

The implementation of this Recommendation in an effective manner is dependent upon Recommendation 2 being implemented. Host country regulations regarding applications of pesticides are applicable if such regulations are more protective of the environment.

Recommendation 7 — **It is recommended that pesticides used should be those with the minimum impact on non-target species.**

Each of the pesticides examined in this report has varying toxicity to associated invertebrates including non-target competitors, predators, parasites, and community/complex species. In addition, some of them are toxic to mammals, birds or fish. Figure 8 indicates which pesticides have minimal impact on non-target organisms for the different ecosystems. Those marked "yes" can be used with caution in the ecosystem indicated. Those marked "caution" should only be used with appropriate mitigative measures and those marked "no" should never be used in the environment indicated.

FIGURE 8

PESTICIDES EFFECT IN AQUATIC AND TERRESTRIAL ECOSYSTEMS

Pesticide	Aquatic	Terrestrial
carbaryl	yes	yes(1)
diazinon	caution(2)	caution(2)
dieldrin	no	no
fenitrothion	caution(2)	caution(2)
lindane	no	no
malathion	caution	yes
propoxur	yes	caution
acephate	yes	yes
bendiocarb	yes(3)	caution
chlorpyrifos	caution	caution (3)
cypermethrin	no	yes
lambda-cyhalothrin	no	yes
tralomethrin	no	yes

(1) not around bees
(2) not to be used around bird nesting sites
(3) testing and data very limited

Recommendation 8 — It is recommended that pre- and post-treatment monitoring and sampling of sentinel organisms and water and/or soils be carried out as an integral part of each control campaign.

In itself, the careful selection of pesticides and the avoidance of spraying in environmentally sensitive areas is not sufficient. Monitoring the impact of the spraying is also necessary and must be carried out as often as possible. Due to the difficulty of carrying out Recommendation 8 under field and laboratory conditions, delays in full implementation are to be expected.

Whenever possible, pre-treatment baseline data for selected organisms or parameters should be established.

APPLICATION OF INSECTICIDES

The approach to be adopted in application should be one of limited, well-timed spraying of carefully designated areas. This, combined with early intervention in the outbreak cycle will be utilized in order to minimize the need for applications. For the Desert Locust, emphasis should be placed upon preventing gregarization. During plagues, swarm control is only appropriate in northern Africa or where swarming locusts congregate prior to moving across mountain barriers. In the Sahel, all emphasis should be on control of nymphs. Nymphs of other species of locust can also be sprayed in breeding and outbreak areas which are geographically limited. In local control programs the use of safe, effective baits should be encouraged and supported. Therefore:

Recommendation 9 — It is recommended that one of the criteria to be utilized in the selection of control techniques should be a minimization of the area to be sprayed.

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

Accuracy in spraying is essential, and ground treatment should be favored over aerial treatment wherever possible.

Recommendation 11 — It is recommended, that whenever possible, small planes should be favored over medium to large two or four engine transport types. In all cases, experienced contractors will be used.

Where aerial spraying is carried out, the following guidelines should be followed:

- o Pilots and contractors who have demonstrated past, proven performance should be selected. Contracts should never be based solely on the basis of a low bid, unless the lowest bid also is a responsible bid. Part of the qualifications for an IQC contract will be the use of pilots pre-qualified in aerial application techniques.

- o Contractors who are able to provide the necessary equipment and trained personnel, both local and expatriate, to properly handle, load and accurately spray the pesticide, should be selected.

- o Mapping, guidance and communication must be in place and adequate prior to any spraying.

With regard to the large plane option, it needs to be recognized that this is not an environmentally sound approach to locust and grasshopper control. There may however, be areas that are only accessible to large planes and if they are to be sprayed this might be the only option. Large planes should always be regarded as the last resort to be used only when no other approach is practical. When large planes are used, extraordinary precautions must be taken, including mandatory environmental supervision and monitoring. Guidelines for the use of large planes are currently being developed by AID.

Recommendation 12 — **It is recommended that any USG-funded locust/grasshopper control actions, which provide pesticides and other commodities, or aerial or ground application services, include techical assistance and environmental assessment expertise as an integral component of the assistance package.**

The technical assistance team would include specialists in survey, aerial and ground control application, logistics, environmental monitoring, communications and training. Given the importance of including environmental considerations in the control effort at the onset, the initial team would carry out an on-the-spot environmental assessment in order to ensure the early identification of specific impact mitigation measures. This EA would also ensure the execution of locust/grasshopper control activities in an environmentally sound manner.

Recommendation 13 — It is recommended that all pesticide containers be appropriately labeled.

Labeling should include basic use pattern information plus appropriate human, wildlife, and environmental precautions. The use of bilingual or multilingual labeling should be considered (e.g., English/French, English/Arabic, English/Portugese).

SECTION III

The Recommendations in this Section are of high priority and should be implemented as soon as resources can be allocated.

DISPOSAL OF INSECTICIDES

Recommendation 14 — It is recommended that AID provide assistance to host governments in disposing of empty pesticide containers and pesticides that are obsolete or no longer usable for the purpose intended.

One of the major environmental hazards growing out of past locust and grasshopper control program, (as well as other pest control programs), is the stock of obsolete and out of date chemicals to be found in many parts of Africa. (These include BHC, aldrin, heptachlor and toxaphene.)

This Recommendation requires that an inventory system for pesticide chemicals be developed under Recommendation 3 above. It is also recommended that OFDA continue its pilot program in appropriate disposal techniques.

PUBLIC HEALTH AWARENESS

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

Public health is an area that has been neglected in the past, but needs to be addressed now.

Recommendation 16 — It is recommended that training courses be designed and developed for health personnel in all areas where pesticides are used frequently.

The purpose of these courses would be to familiarize doctors, nurses and other health workers with the symptomatology of pesticide poisoning and provide information on appropriate measures for first aid, specific treatment, prevention and referral to a hospital center.

<u>Recommendation 17</u> It is recommended that each health center and dispensary located in an area where pesticide poisonings are expected to occur should be supplied with large wall posters in which the diagnosis and treatment of specific poisonings are depicted. The centers and dispensaries should also be provided, prior to spraying, with those medicines and antidotes required for treatment of poisoning cases.

<u>Recommendation 18</u> It is recommended that presently available tests for monitoring human exposure to pesticides should be evaluated in the field. This includes measurement of cholinesterase levels in small samples of blood as a screening test.

Special attention should be given to improving the logistics for specimen collection and preservation. If the presently available methods prove to be inadequate, attempts could be made to develop a cheap semi-quantitative microtest that could be distributed widely. Tests for the direct determination of pesticides and of their metabolites in urine and blood should also be evaluated under different field conditions.

This program could be expanded to include livestock as well as the education of veterinarians and technicians.

PESTICIDE FORMULATION AND MANAGEMENT

<u>Recommendation 19</u> It is recommended that the specifications developed for AID purchase of locust/grasshopper insecticides be adapted for all insecticides.

There are, at present, problems regarding the suitability of some formulations, in addition to labeling and packing of chemicals for use in the countries where they are required for locust and grasshopper control.

Specifications should state that these insecticides be specifically formulated for storage and use under tropical conditions. Specifications presently under development by FAO might be suitable for AID use.

Recommendation 20 — It is recommended that pesticide container specifications be developed.

Containers need to be sufficiently durable for transportation and storage under tropical conditions. Also the size should be appropriate size for the end user, not just the most economical size.

BIOLOGICAL CONTROL

Recommendation 21 — It is recommended that *Nosema* and other biological agents such as Neem be field tested under African and Asian conditions in priority countries.

If locust and grasshopper control is to move beyond solely chemical control there is a need to test pathogens in the field. At present the only one that shows promise is *Nosema*. Currently there is no evidence that *Nosema* can control African or Asian locust and grasshopper populations.

The research and testing should determine the following for each target pest species:

- Optimal application testing
- Efficacy demonstrated in terms of population suppression when compared to chemical insecticides. Successful utilization, in this case, will be dependent upon acceptance of efficacious results by host country officials
- Best application techniques for uniform distribution
- Effects on non-target species.

TRAINING

<u>Recommendation 22</u>

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

AID is already active in the area of training and this should continue. There are some areas in which training programs need to be instituted.

Qualified technical trainers to do the training must be provided. Emphasis in this program should be on sound IPM approaches and environmental concerns, including public health and safety.

<u>Recommendation 23</u>

It is recommended that local programs of training be instituted for pesticide storage management, environmental monitoring and public health (see Recommendation 16).

Training aids need to be provided and updated regularly.

<u>Recommendation 24</u>

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

ECONOMICS

<u>Recommendation 25</u>

It is recommended that field research be carried out to generate badly needed economic data on a country-by-country basis.

A constant problem in trying to evaluate locust and grasshopper control in economic terms is the lack of data. If the benefits of control measures are to be evaluated there is a need for this data.

Locust and grasshopper data must be evaluated in economic terms. Areas that will need to be addressed include:

- What is the range of crop output (yield) over the years?
- What is expected output during an average ("normal") year?
- What is the impact on the output from the locust/grasshopper populations? What crop outputs are consumed or destroyed by other endemic pests?
- What is the effect on output of an uncontrolled locust swarm?
- What amount of output is saved by the various locust control measures?
- What is the total cost -- both local and donor (including FAO) -- of various locust control measures?

Recommendation 26 — **It is recommended that no pesticide be applied unless the provisional economic threshold of locusts or grasshoppers is exceeded.**

The economic threshold for intervention needs to be refined. AID has already contracted, with Oregon State University, for work to be done in this area.

SECTION IV

The Recommendations in this Section have the same priority as those in III, but differ in that they have broader implications, well beyond the locust and grasshopper control program. These Recommendations may be dealt with more appropriately in the overall agricultural and environmental programs of the host countries with the support of AID and other donors.

ENVIRONMENTAL POLICY

Recommendation 27 — **It is recommended that AID provide assistance to host countries in drawing up regulations on the registration and management of pesticides and the drafting of environmental policy.**

Many of the countries involved in locust and grasshopper control programs have no policies regarding the environment, or the use and registration of pesticides. This is an area where the USA is in the forefront and where AID could provide invaluable encouragement, expertise and assistance.

PESTICIDE USE POLICY

Recommendation 28 — **It is recommended that a pesticide use inventory covering all treatments in both agricultural and health programs be developed, on a country-by-country basis.**

Locust and grasshopper control is just one of the many programs responsible for utilizing pesticides. Other programs, both health and agriculture-related are also involved in applying pesticides. Pesticide effects are cumulative and there is a need to develop better information on the extent of and effects from application.

This inventory should then be utilized in the evaluation of health effects, loss of bio-diversity and the need for specific monitoring.

PESTICIDE HANDBOOK

<u>Recommendation 29</u>

It is recommended that AID produce a regularly updated pesticide handbook for use by its staff.

AID should produce a pesticide handbook with application beyond the Locust/Grasshopper Control program laying out policy, planning and implementation for AID programs involving pesticides.

This could be set up in a computerized format similar to the pesticide recommendations published by North Carolina, Oregon, and other states. It can also be provided to host countries and others involved in the use of pesticides.

SUPPORT AND TRAINING

<u>Recommendation 30</u>

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

If the objective for the individual crop protection services of each country eventually accepting the responsibility of controlling locusts and grasshoppers, within the context of a broader crop protection is adopted, then long-term support will be necessary. This will include some technical assistance, training, and equipment.

SECTION V

The implementation of Recommendations in this Section is considered desirable but not of the same urgency as that of the Recommendations in the Sections above.

STORAGE

Recommendation 31 — It is recommended that more pesticide storage facilities be built. Until that occurs, emergency supplies should be pre-positioned in the United States.

Storage for pesticides in many countries involved in locust and grasshopper control programs is frequently insufficent and inadequate.

Pre-positioning or storage in the U.S. is preferred over that in Africa/Asia because:

a. No particular African/Asian country would be burdened with the responsibility for ensuring environmental or health or safety standards, i.e., guarding against potential hazards of storage.

b. Emergency outbreak areas are often unpredictable, thus secondary or further handling/shipment would be likely if pesticides were stored/pre-positioned in selected African/Asian countries.

c. From the U.S., one primary shipment to the target areas for control would be made, i.e., ready availability and direct shipments.

d. Environmental, health, and safety concerns could be better addressed and monitored in the U.S.

presently available methods prove to be inadequate, attempts should be made to develop a cheap semi-quantitative microtest that could be distributed widely. The test for the direct determination of pesticides and of their metabolites in urine and blood should also be evaluated under different field conditions.

Cases with and without specified conditions should be studied for differences in the degree of pesticide exposure and ability of effective detoxification. Health conditions to be considered may include symptomatic schistosomiasis, chronic hepatits, HB antigenemia, pregnancy and birth defects, symptomatic vs. asymptomatic vitamin A deficiency, etc. Likewise, a retrospective comparative study between cases with symptomatic pesticide poisoning and asymptomatic control subjects, heavily exposed to the same pesticides, should be made to identify possible risk factors. Hypothetically, the following health conditions could be considered as pre-disposing factors that decrease pesticide tolerance: skin lesions, malnutrition, vitamin A deficiency, pica (earth eating), and chronic liver diseases.

RESEARCH

<u>Recommendation 34</u> It is recommended that applied research be carried out on the efficacy of various pesticides and growth retardants and their application.

Specific areas to be addressed include:

- o development of a bait for aerial application containing a feeding attractant and/or stimulant in addition to the insecticide
- o use of No-Moult as a growth retardant
- o bendiocarb as bait
- o chlorpyrifos as barrier spray
- o carbaryl as barrier spray
- o carbaryl as bait
- o acephate on dry vegetation
- o propoxur as liquid spray
- o development of slow-release formulations

<u>Recommendation 35</u> **It is recommended that applied research be carried out on the use of Neem as an anti-feedant.**

There is also a need to determine how effective anti-feedants can be as part of an IPM approach to locust and grasshopper control. At present the anti-feedant that shows some promise is Neem.

<u>Recommendation 36</u> **It is recommended that research be carried**

FORECASTING

Recommendation 32

It is recommended that AID make a decision as to whether to continue funding forecasting and remote sensing or utilize the FAO's early warning program.

Any locust and grasshopper control program can be more effective if good forecasting methods are developed. The most promising methods of forecasting presently under development rely upon remote sensing. AID can opt for continuing to develop the remote sensing methods for locust and grasshopper early warning and environmental monitoring that it has been sponsoring under its own aegis, or it can propose that locust and grasshopper control teams use the services of the FAO's locust early warning program and its upcoming part in the ARTEMIS system. The first option gives AID more control over its data and procedures, but at the expense of overseeing and funding the effort. In the second case it would lose a certain amount of control over the information, but gain access to a remote sensing and pest early warning program that is already semi-operational and apparently well advanced in program planning.

If the decision selects the FAO option, then effective liaison needs to be set up to ensure that FAO provides good, on time information to all locust and grasshopper control programs, conducted by regional organizations, missions and host countries.

PUBLIC HEALTH MONITORING AND STUDY

Recommendation 33

It is recommended that a series of epidemiologic case-control studies, within the countries involved in locust and grasshopper control, should be implemented in areas of heavy human exposure to pesticides.

There is a need to develop more information on the public health impact of pesticides in the countries where the locust and grasshopper treatment is being carried out. Health and nutrition in many of these countries is markedly different from that of the industrialized world and the impact on the human population could be very different.

Presently available tests for monitoring human exposure to pesticides should be conducted at field level. This includes measurement of cholinesterase levels in samples of blood as a screening test. Special attention should be given to improving the logistics for specimen collection and preservation. If the out to determine the best techniques for assessing the impacts of organophosphates used for locust and grasshopper control "in relation" to the use of these and other chemicals for other pest control programs.

SECTION VI

The implementation of the above 36 Recommendations can be facilitated and accelerated by developing and then following the appropriate procedures. To this end two final Recommendations are presented here.

Recommendation 37

It is recommended that AID, on the basis of the previous Recommendations, develop a plan of action with practical procedures to provide guidance in locust/grasshopper control to missions in the field.

Recommendation 38

It is recommended that detailed guidelines be developed for AID to promote common approaches to locust and grasshopper control and safe pesticide use among UN Agencies and donor nations. Coordination of efforts is becoming increasingly important because of the increasing number and magnitude of multilateral agreements and follow up efforts in subsequent years by various donors.

The three volume PEA for Locust and Grasshopper Control was prepared by the following persons:

Dr. John Buursink	Teamleader/Natural Resource Planner
George Cavin	Team Coordinator/ Locust/Grasshopper Entomologist
Dr. Alfred A. Buck	Public Health Specialist
Dr. James C. Cate, Jr.	Biocontrol Specialist
Dr. Jon C. Cooper	Acquatic Ecologist
Charles J. Dorigan	Environmental Specialist
Dr. Virgil H. Freed	Pesticide Impact Specialist
Janice K. Jensen	Pesticide Disposal Specialist
Dr. Patricia C. Matteson	Integrated Pest Management Specialist
Frank E. Peacock	Natural Resources Economist
Dr. James A. Sherburne	Terrestrial Ecologist
Mark G. Thompson	Deputy Teamleader/ Environmental Scientist
Dr. Carroll M. Voss	Pesticide Application Specialist

across borders so that control measures benefit from an international approach. The distribution of the Senegalese Grasshopper is shown in Figure 3. Wherever reference is made to

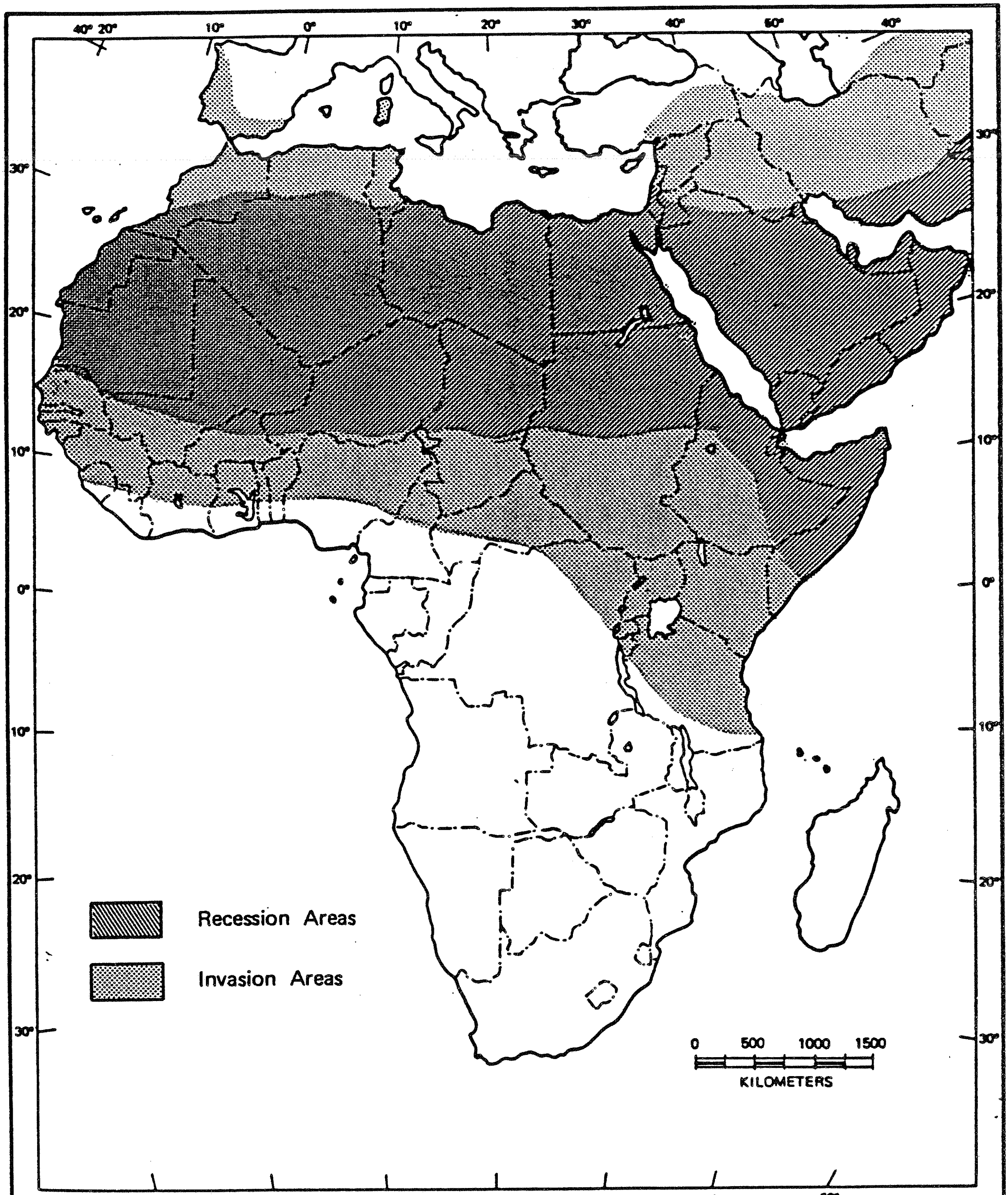

Figure 1. Invasion and recession areas of the <u>Desert Locust</u>
Source: Waloff, 1976

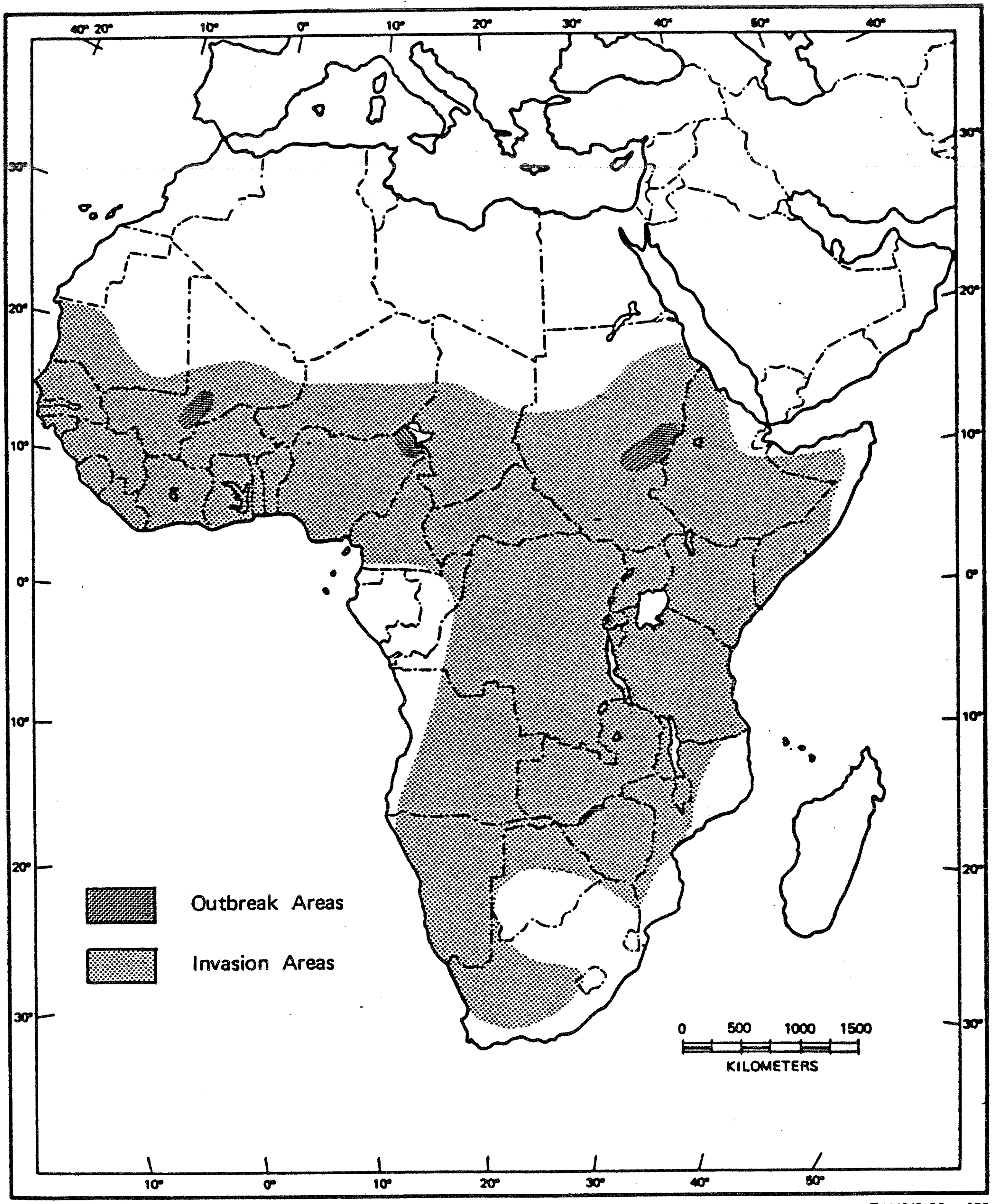

Figure 2. Outbreak and invasion areas of the African Migratory Locust
Source: USAID, 1987b, and G. Cavin, 1987

grasshoppers in this report, only the above three species are meant. Other grasshoppers are not considered unless specifically mentioned.

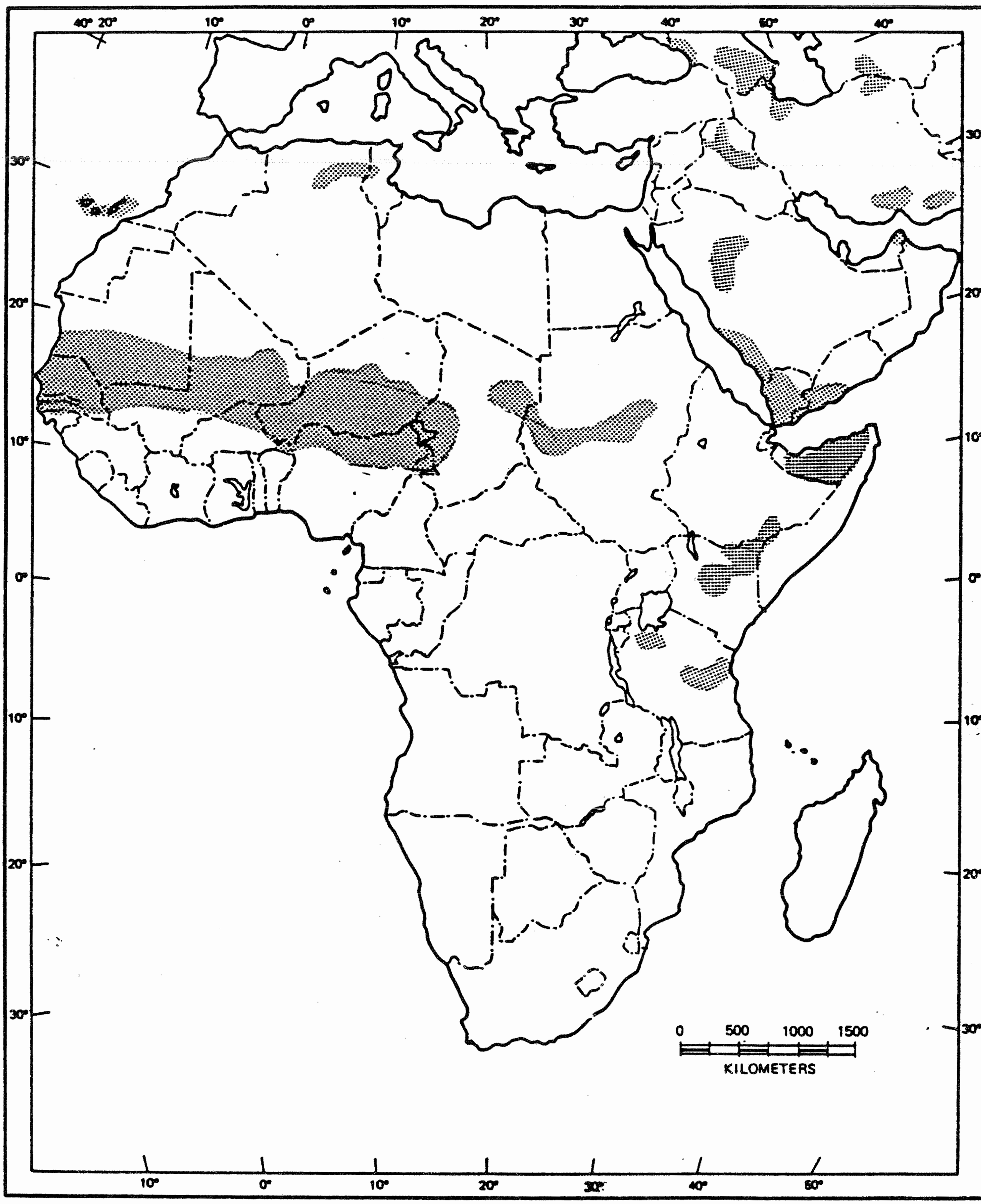

Figure 3. Distribution of the Senegalese Grasshopper
Source: Batten, 1969, and information from later sources

A.4 Impact of Locust and Grasshopper Outbreaks

The impact of locusts and grasshoppers on the natural environment, trees, shrubs and rangeland is incompletely documented. This may be because the impact is not great, or not perceived as great by the local population and government agencies in Africa and South West Asia.

With regard to the impact of locusts and grasshoppers on crops, three words are frequently linked: locust - plague - famine. In fact, there is no convincing evidence that the impact on crops is anything as severe as that of drought - or similar major disasters. Impacts are localized rather than nation-wide, and crop loss is seldom total.

A.5 Cost of Locust and Grasshopper Damage

In view of the paucity of agricultural data for much of Africa and parts of Southwest Asia, the incompleteness of data on crop losses and the lack of reported locust and grasshopper damage, the cost of such damage is hard to assess. In 1986 FAO estimated crop losses due to locusts and grasshoppers in nine Sahelian countries at $31,000,000, or 1.5% of the total value of agricultural production in the countries concerned. But such is the paucity of data that it is not clear whether this 1986 figure is above or below average, greater or less than other years or for other recorded outbreaks. After decades of locust and grasshopper control, it is simply not clear how much damage locusts and grasshoppers do.

A.6 Current Locust and Grasshopper Control

Although various nonchemical and selective chemical control methods are at the research and testing stage, broad-spectrum insecticides are the only effective control weapon against grasshopper and locust outbreaks that is currently available.

Having such chemicals, national pest control organizations have concerned themselves primarily with the Brown, Moroccan and Tree Locusts. The other species covered by an array of specialized regional locust control organizations created between 1949 and 1962. For the Desert Locust, which last held plague status in 1962, control participants have been: three regional FAO Commissions directing member states' operations in Northwest Africa, the Near East and Southwest Asia; the Desert Locust Control Organization for Eastern Africa (DLCO/EA); and the Organisation commune de Lutte antiacridienne et de Lutte Antiaviaire (OCLALAV) in West Africa. African Migratory Locust outbreak areas in Mali and the Lake Chad basin have been patrolled by the Organisation Internationale contre le Criquet Migrateur Africain (OICMA). The International Red Locust Control