

WDP284  
April 1995

284



World Bank Discussion Papers

---

# Desert Locust Management

## A Time for Change

---

Steen R. Joffe

## Recent World Bank Discussion Papers

- No. 227 *Cities without Land Markets: Lessons of the Failed Socialist Experiment.* Alain Bertaud and Bertrand Renaud
- No. 228 *Portfolio Investment in Developing Countries.* Edited by Stijn Claessens and Sudarshan Gooptu
- No. 229 *An Assessment of Vulnerable Groups in Mongolia: Strategies for Social Policy Planning.* Caroline Harper
- No. 230 *Raising the Productivity of Women Farmers in Sub-Saharan Africa.* Katrine Saito
- No. 231 *Agricultural Extension in Africa.* Aruna Bagchee
- No. 232 *Telecommunications Sector Reform in Asia: Toward a New Pragmatism.* Peter L. Smith and Gregory Staple
- No. 233 *Land Reform and Farm Restructuring in Russia.* Karen Brooks and Zvi Lerman
- No. 234 *Population Growth, Shifting Cultivation, and Unsustainable Agricultural Development: A Case Study in Madagascar.* Andrew Keck, Narendra P. Sharma, and Gershon Feder
- No. 235 *The Design and Administration of Intergovernmental Transfers: Fiscal Decentralization in Latin America.* Donald R. Winkler
- No. 236 *Public and Private Agricultural Extension: Beyond Traditional Frontiers.* Dina L. Umali and Lisa Schwartz
- No. 237 *Indonesian Experience with Financial Sector Reform.* Donald P. Hanna
- No. 238 *Pesticide Policies in Developing Countries: Do They Encourage Excessive Use?* Jumanah Farah
- No. 239 *Intergovernmental Fiscal Relations in Indonesia: Issues and Reform Options.* Anwar Shah and Zia Qureshi, with Amaresh Bagchi, Brian Binder, and Heng-fu Zou
- No. 240 *Managing Redundancy in Overexploited Fisheries.* Joshua John
- No. 241 *Institutional Change and the Public Sector in Transitional Economies.* Salvatore Schiavo-Campo
- No. 242 *Africa Can Compete! Export Opportunities and Challenges for Garments and Home Products in the U.S. Market.* Tyler Biggs, Gail R. Moody, Jan-Hendrik van Leeuwen, and E. Diane White
- No. 243 *Liberalizing Trade in Services.* Bernard Hockman and Pierre Sauvé
- No. 244 *Women in Higher Education: Progress, Constraints, and Promising Initiatives.* K. Subbarao, Laura Raney, Halil Dundar, and Jennifer Haworth
- No. 245 *What We Know about Acquisition of Adult Literacy: Is There Hope?* Helen Abadzi
- No. 246 *Formulating a National Strategy on Information Technology: A Case Study of India.* Nagy Hanna
- No. 247 *Improving the Transfer and Use of Agricultural Information: A Guide to Information Technology.* Willem Zijp
- No. 248 *Outreach and Sustainability of Six Rural Finance Institutions in Sub-Saharan Africa.* Marc Gurgand, Glenn Pederson, and Jacob Yaron
- No. 249 *Population and Income Change: Recent Evidence.* Allen C. Kelley and Robert M. Schmidt
- No. 250 *Submission and Evaluation of Proposals for Private Power Generation Projects in Developing Countries.* Edited by Peter A. Cordukes
- No. 251 *Supply and Demand for Finance of Small Enterprises in Ghana.* Ernest Aryeetey, Amoah Baah-Nuakoh, Tamara Duggleby, Hemamala Hettige, and William F. Steel
- No. 252 *Projectizing the Governance Approach to Civil Service Reform: An Institutional Environment Assessment for Preparing a Sectoral Adjustment Loan in the Gambia.* Rogerio F. Pinto with assistance from Angelous J. Mrope
- No. 253 *Small Firms Informally Financed: Studies from Bangladesh.* Edited by Reazul Islam, J. D. Von Pischke, and J. M. de Waard
- No. 254 *Indicators for Monitoring Poverty Reduction.* Soniya Carvalho and Howard White
- No. 255 *Violence Against Women: The Hidden Health Burden.* Lori L. Heise with Jacqueline Pitangy and Adrienne Germain

(Continued on the inside back cover.)

284



World Bank Discussion Papers

---

# Desert Locust Management

## A Time for Change

---

Steen R. Joffe

The World Bank  
Washington, D.C.

Copyright © 1995  
The International Bank for Reconstruction  
and Development/THE WORLD BANK  
1818 H Street, N.W.  
Washington, D.C. 20433, U.S.A.

All rights reserved  
Manufactured in the United States of America  
First printing April 1995

Discussion Papers present results of country analysis or research that are circulated to encourage discussion and comment within the development community. To present these results with the least possible delay, the typescript of this paper has not been prepared in accordance with the procedures appropriate to formal printed texts, and the World Bank accepts no responsibility for errors. Some sources cited in this paper may be informal documents that are not readily available.

The findings, interpretations, and conclusions expressed in this paper are entirely those of the author(s) and should not be attributed in any manner to the World Bank, to its affiliated organizations, or to members of its Board of Executive Directors or the countries they represent. The World Bank does not guarantee the accuracy of the data included in this publication and accepts no responsibility whatsoever for any consequence of their use. The boundaries, colors, denominations, and other information shown on any map in this volume do not imply on the part of the World Bank Group any judgment on the legal status of any territory or the endorsement or acceptance of such boundaries.

The material in this publication is copyrighted. Requests for permission to reproduce portions of it should be sent to the Office of the Publisher at the address shown in the copyright notice above. The World Bank encourages dissemination of its work and will normally give permission promptly and, when the reproduction is for noncommercial purposes, without asking a fee. Permission to copy portions for classroom use is granted through the Copyright Clearance Center, Inc., Suite 910, 222 Rosewood Drive, Danvers, Massachusetts 01923, U.S.A.

The complete backlist of publications from the World Bank is shown in the annual *Index of Publications*, which contains an alphabetical title list (with full ordering information) and indexes of subjects, authors, and countries and regions. The latest edition is available free of charge from the Distribution Unit, Office of the Publisher, The World Bank, 1818 H Street, N.W., Washington, D.C. 20433, U.S.A., or from Publications, The World Bank, 66, avenue d'Iéna, 75116 Paris, France.

ISSN: 0259-210X

Steen R. Joffe is a consultant to the Agricultural Technology and Services Division of the World Bank's Agriculture and Natural Resources Department.

#### **Library of Congress Cataloging-in-Publication Data**

Joffe, Steen, 1957 –

Desert locust management : a time for change / Steen Joffe.

p. cm. — (World Bank discussion paper ; 284)

Includes bibliographical references (p. ).

ISBN 0-8213-3229-5

1. Desert locust —Control. I. Title. II. Series: World Bank

discussion papers ; 284.

SB945.D44J64 1995

338.1'62 —dc20

95-13794  
CIP

# CONTENTS

<b>FOREWORD</b> .....	v
<b>ABSTRACT</b> .....	vi
<b>ACKNOWLEDGMENTS</b> .....	vii
<b>EXECUTIVE SUMMARY</b> .....	ix
<b>CURRENT SITUATION</b> .....	1
<b>Locust Control Strategy</b> .....	1
How plagues begin and end .....	1
Technical challenges to strategy.....	5
Control strategies defined.....	5
Attempting preventive control.....	9
Survey and control costs .....	11
<b>Technology for Locust Control</b> .....	13
Finding and forecasting locusts .....	13
Chemical control and pesticide choice .....	15
Pesticide application techniques and the dieldrin dilemma.....	16
<b>Institutions</b> .....	17
Past as prologue.....	17
International .....	17
Regional organizations and activities .....	18
National plant protection services .....	21
Donors .....	21
<b>ISSUES</b> .....	25
<b>Incomplete Rationale for Control</b> .....	25
Limited damage estimates .....	25
Nature of impacts.....	25
Politics over analysis .....	26
<b>Lack of Effective Strategy</b> .....	27
Preparedness needed.....	28
Is upsurge prevention viable? .....	28
<b>Can Desert Locust Control be Based on an IPM Strategy?</b> .....	30
<b>How to Safeguard the Environment?</b> .....	32
Sources of risk.....	32
Mitigating actions .....	33
<b>Lack of Data and Information Flow</b> .....	36
<b>Ineffective Action and International Coordination</b> .....	38
Disparate national capacity and response.....	38
Management and oversight.....	39
Aid dependency.....	40
<b>RECOMMENDATIONS</b> .....	44
<b>Strategic Framework</b> .....	44
<b>National Programs and Regional Networks</b> .....	44
<b>Donors' Supporting Roles</b> .....	45
<b>Regional Preventive Control</b> .....	47
<b>Risk Assessment and International Control Policy</b> .....	47
<b>Consensus and Change</b> .....	50
<b>REFERENCES</b> .....	51

<b>Appendix: ULV pesticides for Desert Locust control.....</b>	<b>57</b>
--	-----------

## MAPS

<b>Desert Locust Gregarization Sites and Distribution Area .....</b>	<b>3</b>
<b>Desert Locust Seasonal Plague Breeding Areas. ....</b>	<b>7</b>
<b>Regional Organizations and FAO Commissions in Charge of Locusts and Grasshopper Control.....</b>	<b>19</b>

## LIST OF BOXES

<b>1. Desert Locust biology and behavior.....</b>	<b>10</b>
<b>2. Lessons learned from Desert Locust control activities: 1928-94 .....</b>	<b>12</b>
<b>3. Spray techniques for locust control.....</b>	<b>16</b>
<b>4. Financing Desert Locust control.....</b>	<b>22</b>
<b>5. How Algeria organizes locust control. ....</b>	<b>23</b>
<b>6. Agricultural policy: program response to risk from Desert Locusts. ....</b>	<b>29</b>
<b>7. USAID's intervention thresholds for locust control.....</b>	<b>30</b>
<b>8. Potential alternatives to current methods of Desert Locust control.....</b>	<b>34</b>
<b>9. Assessing environmental impacts of locust control activities. ....</b>	<b>36</b>
<b>10. Satellite imaging and modeling of locust behavior .....</b>	<b>37</b>
<b>11. FAO's proposed emergency prevention system (EMPRES).....</b>	<b>48</b>

## LIST OF FIGURES

<b>1. The Desert Locust <i>Schistocerca Gregaria</i>. ....</b>	<b>11</b>
<b>2. Desert Locust forecasting, assessment and early control (after FAO, 1993). ....</b>	<b>14</b>
<b>3. Donor assistance to locust &amp; grasshopper control: 1986-94.....</b>	<b>24</b>
<b>4. Regional breakdown of locust &amp; grasshopper assistance, 1986-94 .....</b>	<b>24</b>
<b>5. Building blocks of locust management.....</b>	<b>46</b>

## LIST OF TABLES

<b>1. FAO estimates of Desert Locust survey and early control costs .....</b>	<b>13</b>
<b>2. Donor assistance to locust and grasshopper control programs, 1986-94 (US\$ million).....</b>	<b>24</b>
<b>3. Estimates of crop losses caused by Desert Locusts, 1925-89.....</b>	<b>27</b>
<b>4. Countries affected by Desert Locust: agriculture indicators, production threatened and assistance received.....</b>	<b>41</b>
<b>5. Strategic shifts required in Desert Locust management. ....</b>	<b>44</b>

# FOREWORD

Plagues of the Desert Locust are occurring, on average, one year in every six. Swarms can potentially affect crops and grazing in some sixty five countries stretching across a large belt of Africa, the Middle East and South Asia. Over the last ten years two major upsurges have occurred and international development agencies, including the World Bank, have contributed some US\$383 million to emergency control operations.

This paper highlights a number of issues associated with these operations. One key question concerns the extent to which the rationale for control is based on a realistic assessment of the risks posed to agricultural production and livelihoods. At the same time, it appears that a lack of preparedness on the part of all major actors is contributing to the 'emergency' status of control operations. When operations are undertaken, questions frequently arise as to whether an effective technical strategy is employed, given the logistical, institutional and resource constraints that exist. This is undoubtedly contributing to inefficiencies and increased environmental costs. Moreover, sustainable capacity is not being developed in most of the affected countries and donor dependence is high.

In the face of these difficulties little agreement exists amongst the main parties - affected countries, donors, and FAO (the lead agency) - on how to proceed. The paper is intended as a contribution to the current debate. It is argued that a major rethink is now needed of how the Desert Locust problem is assessed and how control measures are financed and implemented. A number of specific suggestions are made on measures that could be taken at national, regional and international levels, including the targeting of control operations based on transparent threshold criteria. It is suggested that little progress will be possible until affected countries, donors and FAO are able to unite behind an agreed long-term management strategy.

Alexander McCalla  
Director  
Agriculture and Natural  
Resources Department

## ABSTRACT

Plagues of the Desert Locust are occurring, on average, one year in every six. Highly mobile swarms may then threaten a vast territory stretching from Mauritania to India, and Turkmenistan to Tanzania. In the last ten years two major upsurges have occurred. Development agencies including the World Bank have assisted the control efforts of affected countries; financial assistance totaled some US\$383 million over this period.

This paper highlights a number of issues associated with these operations. One key question concerns the extent to which the rationale for control is based on a realistic assessment of the risks posed to agricultural production and livelihoods. At the same time, it appears that a lack of preparedness on the part of all major actors is contributing to the 'emergency' status of control operations. When operations are undertaken it is not clear that an effective technical strategy currently exists, or is being employed, given logistical, institutional and resource constraints. This is contributing to inefficiencies and increased environmental costs. Moreover, sustainable capacity is not being developed in most of the affected countries and donor dependence is high.

Little agreement exists amongst the main parties - affected countries, donors, and FAO (the lead agency) - on how to deal with these problems. The paper contributes to the ongoing debate on these questions with several specific suggestions. A key proposal is that the strategy for control should shift from one which seeks to prevent an upsurge occurring (which has not been possible so far) to one that is closer to the integrated pest management (IPM) approach, where a variety of means are used to keep economic, social and environmental impacts below acceptable threshold limits.

Initiatives are identified at national, regional and international levels. Donors can help affected countries in a number of ways through long term country assistance grants and loans, including assistance to develop improved policies, early warning systems, contingency plans and control strategies linked to environmental impact assessments. Not all countries can justify the expenditure on significant locust control capacity and the building of regional cooperative links is important; however these will only be sustainable if mechanisms are established to ensure long term financing by member countries. Gaps in critical minimum capacity, for example in key potential outbreak areas around the Red Sea, could be addressed through a collaborative regional effort to develop the requisite technologies, institutions and policies.

The role of the international community is also discussed. Several measures are suggested to improve the speed of response should internationally coordinated control efforts be required. A key issue is the need to target assistance efforts effectively according to assessed needs; a related need is to improve the transparency of decision-making based on a set of agreed threshold criteria. Ultimately, it is argued, little progress will be possible until affected countries, donors and FAO are able to unite behind an agreed management strategy. The paper suggests that FAO leads a dialogue with the main stakeholders with a view to developing a specific Desert Locust policy.



## **ACKNOWLEDGMENTS**

This paper draws substantially on the work of consultants, in particular the considerable efforts and helpful advice of Joyce Magor, Hans Dobson and Mark Ritchie (Natural Resources Institute, Chatham, UK). Sharon Blinco also made an important contribution. The author is grateful for comments, advice and encouragement provided by Douglas Forno, Nick van der Graaf (Chief of the Plant Protection Service, FAO), Keith Cressman (FAO/ECLO), Arnold van Huis (Wageningen Agricultural University), Laurent Msellati and Shiv Singh. Many thanks are also due to Sanjiva Cooke for data gathering and analysis, and to Grace Aguilar for processing successive drafts.

The Working Paper: 'Desert Locust Control Operations and Their Environmental Impacts', by Mark Ritchie and Hans Dobson, is available from the World Bank, Agricultural Technology and Services Division (AGR TN), on request.



## EXECUTIVE SUMMARY

The Desert Locust is a much feared pest. It has great mobility and a vast invasion area. Its ecology and behavior create special perhaps unique challenges in the design of management strategies. Over the last ten years some US \$383 million have been committed by the international community in grants and loans to support affected countries facing Desert Locust upsurges through large-scale emergency control campaigns. Criticisms are building, leveled at FAO (the lead agency), donors and affected countries, for their management of these operations. Problems are seen to exist in several areas:

- The rationale for control tends to be based as much on political considerations and emotive arguments as any realistic assessment of the risks to agricultural production and livelihoods;
- The emergency status of recent operations has largely been a function of unpreparedness on all sides;
- there is a lack of clarity and consistency in technical strategy;
- chemical spray campaigns as currently employed can be costly, wasteful of resources, and damaging to the environment;
- interest, resources and capacity wane when the locusts are in recession; essential surveys are not undertaken; little sustainable capacity has been developed in affected countries.

This discussion paper explores the above issues; it aims to stimulate discussion on ways to achieve a more satisfactory situation. The paper does not set out World Bank policy but strongly encourages the elaboration of a consistent and broadly accepted policy by multilateral and bilateral agencies, in partnership with locust affected countries and other stakeholders.

'Preventive control', i.e. checking the build up of the locust population as a whole to avoid risks to agriculture, has been the stated policy of FAO for some 30 years. For at least the last two major upsurges (1985-89 & 1992-94), this strategy has failed. In part the problems are institutional. Support for the regional control organizations has declined and responsibility has passed to national plant protection services. However the countries affected by the Desert Locust are diverse; there are major differences in both willingness and capacity to take effective and early action. Combined with logistical constraints and security problems in some areas, the necessary coverage of key Desert Locust breeding and outbreak sites - regular monitoring, timely reports of locust activity, control where necessary - cannot be assured.

Major differences of opinion exist over control strategy and the means to keep economic and environmental costs within acceptable limits. The areas involved are enormous - when breeding conditions are favorable, with current technology, it may simply be impossible to find and control a sufficient proportion of the population to prevent an upsurge developing. The lack of a suitable persistent control agent is a key constraint here. There can be advantages to waiting until denser, sprayable targets have formed - this strategy envisages the elimination of an upsurge during development and is likely to be more efficient in terms of environmental impacts and costs. Some experts contend that the most cost-efficient option would be to abandon efforts to prevent an upsurge and concentrate instead on swarm control combined with limited crop protection measures.

In aggregate terms, the Desert Locust is not considered to represent a major threat to food security in Africa. The rationale driving control measures is not so much the absolute level of damage likely, but the concern over where, and to whom, any damage will be inflicted. With presently available technology, the case for control on economic and social grounds is generally unconvincing, except where high value agriculture systems or particularly vulnerable subsistence communities are threatened.

Problems in targeting control measures are both technical - the lack of decision tools linking socio-economic impact data to the efficacy and costs of different control options - and political; the predominant perception is that there is a need to act against Desert Locusts, and be seen to act, irrespective of whether significant impacts are likely.

There is currently little consensus amongst technical experts, donors and affected countries, on how to proceed; fundamental questions of strategy, institutional roles and responsibilities, and associated assistance needs, remain unresolved. The major donors have voiced concerns about the leadership and vision provided by the present FAO committee structure. With an adversary as demanding as the Desert Locust, this lack of consensus between the concerned parties is a major drawback.

## **The Way Forward**

It is essential that the countries affected, and the donor community, find the means to unite behind an agreed long-term management strategy for the Desert Locust. In doing so it is clear that a major strategic shift will be required. The over-riding need to pursue the prevention or elimination of an upsurge at all costs can no longer be accepted: *For the future, control strategies should be based on the principles of integrated pest management (IPM), so that the risks associated with the Desert Locust are assessed and mitigated by a variety of available means designed to keep economic, social and environmental impacts within acceptable threshold limits.*

Initiatives are needed at three levels: national, regional and international:

### **1. National Programs and Policies**

(i) The national policies and programs adopted by affected countries are the fundamental building blocks of an internationally effective Desert Locust management plan. These need to cover:

- policies and systems to analyze and mitigate agricultural instability and risk
- integrated information and early warning systems
- contingency plans in the event of a threatened upsurge
- national locust control and applied research strategy linked to an environmental impact statement
- cross border agreements and initiatives in the context of a regionally consistent management plan

(ii) Donors should provide affected countries with technical assistance to support improved policies, control strategies and information systems for Desert Locust management. The full range of available measures to identify, assess and mitigate specific agricultural risk associated with Desert Locusts should be considered including, for example, crop insurance.

(iii) Support for control capacity, including provision of pesticides, should be based on, and contingent on development of the locust control policy and the environmental impact statement. Not all affected countries can currently justify significant anti-locust capacity on economic grounds. Where this is the case, donors should help countries to identify and maintain a critical minimum permanent survey and early warning capacity.

(iv) Timely reporting by affected countries on locust habitats and distribution, and on control operations, is vital, to guide and inform wider regional and international efforts; specific agreements should be reached to ensure that this information is available.

## **2. Regional Initiatives**

(i) Regional cooperation in anti-locust efforts is essential, however establishing additional regional programs or structures won't solve existing structural problems. A complete review of regional level systems for locust survey and control is now needed including the identification of sustainable cost-sharing arrangements by locust-affected countries; direct donor financing is not an effective or viable long term solution.

(ii) Gaps in critical minimum capacity in key potential outbreak areas need to be addressed - the main priority is widely acknowledged to be those sites in the central Desert Locust region around the Red Sea and Arabian Peninsular which are often implicated in upsurges. This will need a collaborative effort over a defined time-frame (e.g. 10 years) to build robust and low cost capacity. Important progress could be made through effective coordination and field application of several existing donor supported R&D initiatives in partnership with national institutions. A multidisciplinary effort will be needed in order to provide some answers on appropriate and cost-effective control tactics, and to expand the scope of the work to address the necessary strengthening of policies and institutions.

## **3. International Intervention**

(i) Until upsurges can be prevented or eliminated in all major Desert Locust regions, which means for the foreseeable future, it must be assumed that further international intervention in Desert Locust control will be required. Much better preparedness is needed. There will be a need to ensure:

- the requisite flexibility to resource campaigns that are regional in scope
- operation of a consistent and cost-effective strategy
- de-politicization of assistance
- targeted control on the basis of social, economic and environmental criteria

(ii) A transparent mechanism for decision-making is needed. A recognized system of threshold criteria should be established to allow control responses to be defined based on assessed and defined risks to agricultural systems, communities, and the environment. Such criteria will need to be elaborated from the bottom-up, initially in national control policy statements, then aggregated for the needs of agencies at regional or international levels. Routine evaluation of impacts of locust infestations is essential and should become standard in donor-supported operations.

(iii) When an internationally coordinated campaign does become necessary, it should be rapid and effective. Donors should establish the resources and systems to effect a campaign well in advance, including activation of consolidated regional funds and mechanisms to ensure rapid access to appropriate chemical control agents where a verified need exists (i.e. the 'pesticide bank' concept). Emergency bi-lateral assistance is not an effective means to match the supply and demand for anti-locust operations. An alternative mechanism needs to be found. One option would be to resource international campaigns through consolidated funds and give direct responsibility for campaign management to a single lead agency.

The ideas and suggestions made here present some significant challenges, both in terms of the status of technical knowledge and tools, and the political consensus needed to arrive at transparent criteria for control operations and donor assistance. Important changes are needed in Desert Locust management. The process of change needs to be managed in a way that combines increasing self-reliance in locust control on the part of the affected countries with a commitment to adequately support this process on the part of donors. Building consensus on needs, priorities and strategies will not be easy or rapid and requires active leadership by FAO and the Desert Locust Control Committee. This paper recommends that FAO leads a dialogue among the primary stakeholders with a view to the development of a specific Desert Locust policy paper.



# CURRENT SITUATION

## Locust Control Strategy

### How plagues begin and end

Desert Locust breeding and seasonal migration patterns ignore national boundaries, so it is only with international cooperation that lasting solutions can be found to the prevention, control and suppression of locust plagues. Crops and grazing in 20 per cent (28 million sq. km) of the earth's surface, including over 65 countries in Africa, the Middle East and southwestern Asia, are intermittently subject to swarm invasion (see Map: Desert Locust Gregarization Sites and Distribution Area).

Initial outbreak areas are in remote semi-arid areas in the Sahara, on the Arabian Peninsula, and along the borders of India and Pakistan. Plagues begin when sequences of exceptional rainfall occur in several potential outbreak areas simultaneously, often in the wake of drought. Under these conditions a generalized upsurge in the Desert Locust population may occur. Analysis of past events shows each plague starting at different sites and preceded by different migration sequences. Only rarely does consecutive seasonal breeding occur in the same sites in successive years or even successive decades (FAO, 1968). This mobility makes the logistics of Desert Locust control and contingency planning uniquely difficult and explains why so few quantitative populations studies exist for developing predictive models.

Between plagues, when Desert Locust numbers and densities are low, they are found only in drier, central parts of the total area. Covering some 16 million sq. km, this smaller zone is known as the recession area. It contains more than 25 countries and extends from Mauritania to northwest India. Appropriately, the recession area is the focal point for surveillance of locust breeding and early control of locust populations. Opportunities for successful locust breeding increase as swarms fly out of the recession area into areas with heavier and more reliable rain (see Map: Desert Locust Seasonal Plague Breeding Areas). After a period of expansion and increasing swarm sizes, plagues decline, taking up to two years to end, and the order in which the plague recedes from a region varies.

The ninth plague since 1860 ended in 1989 (followed by a major upsurge in 1992-94). These plagues varied in length from one to twenty-two years and their onsets and declines were not simultaneous in all regions. Before 1963, a plague occurred in four of every five years, but since then, recessions have predominated, with plagues occurring one year in six. It is not known whether improved control, increased drought, or a combination of the two caused this change.

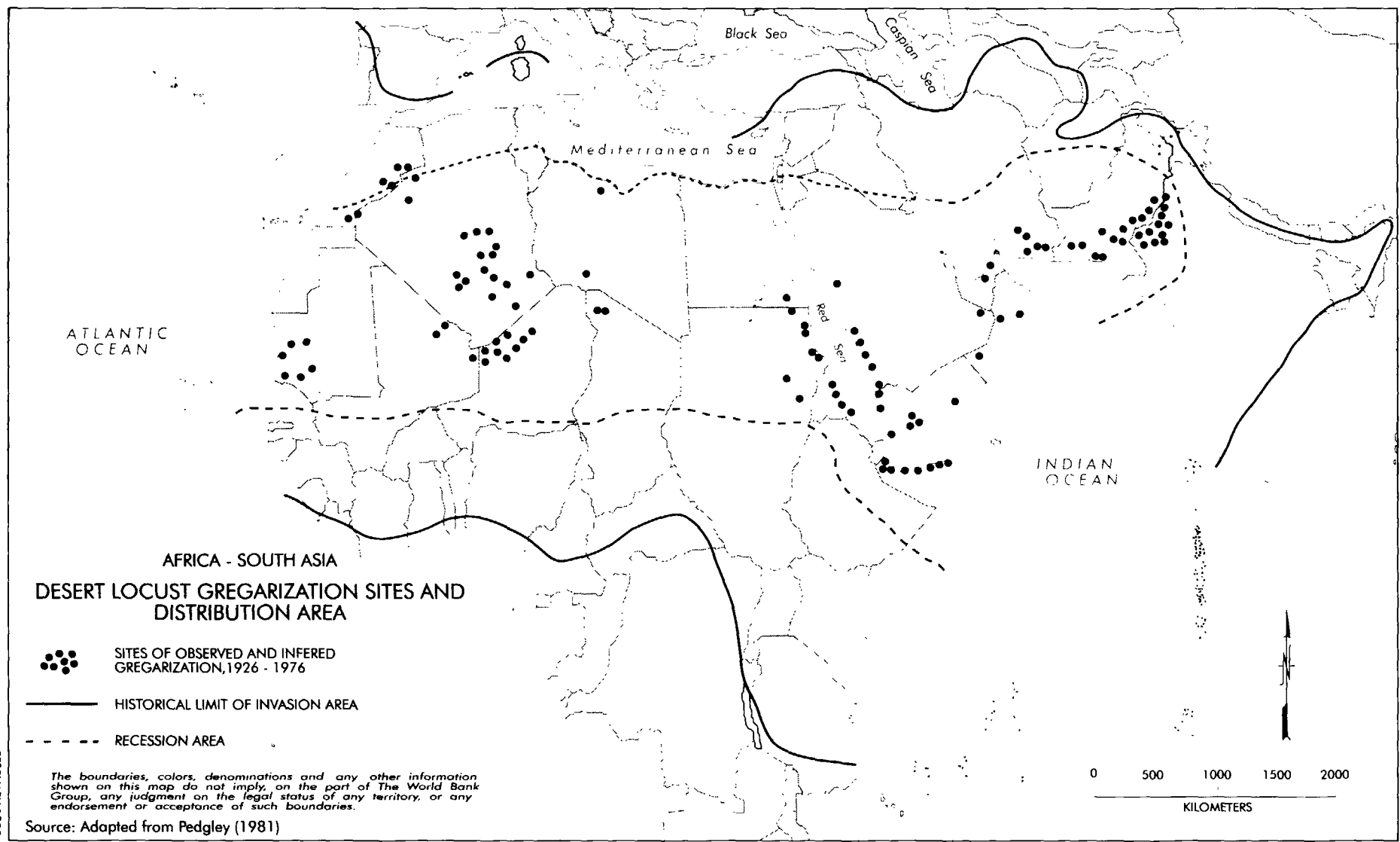
Three factors are cited as playing a role in ending plagues:

- Insufficient rainfall,
- Movement of swarms to areas unsuitable for breeding and survival, and
- Control efforts – predominantly based on chemical methods.

The relative importance of these factors is not always clear. There are few reliable data available to assess either the efficacy of, or economic returns to, chemical control. Lack of rainfall, cool temperatures and wind patterns that cause a decline in locust breeding and migration, may be more important factors in the decline of plagues. Desert Locust plagues started, spread and declined long before effective pesticides and application methods existed.







FEBRUARY 1995

IBRD 26370



## Technical challenges to strategy

Modern locust studies and control strategies began in the 1920s, with the findings of Uvarov (1921) and Faure (1923) that solitary and gregarious locusts were one, not two species and that swarms form and plagues are initiated in geographically restricted zones (see Box 1).

The first-order technical challenges, then and now, are:

- Acquire sufficient knowledge on Desert Locust biology and behavior.
- Find locusts in their breeding habitats.
- Forecast locust population, density and migration.
- Develop method(s) to stop a potential plague, in the face of favorable breeding conditions, or to end one expeditiously, preferably before locusts attack crops.

## Control strategies defined

Locust control – like all pest management – aims at protecting agricultural production. The prevailing strategy for locusts is preventive control, aimed at preventing plagues arising and spreading to agricultural areas where they can cause damage to subsistence and cash crops. While this goal is widely, if not universally, agreed upon, the environmentally and economically desirable moment for intervention is still disputed, as reflected in variants of preventive control, discussed below. Equally, concerns about the safety of chemical control measures have increased with time and application.

**Crop Protection.** Historically, locust control involved individual farmers protecting their crops by burning, beating, building barriers and digging trenches. In the 1930s and early 1940s, as the interaction between potential damage and the locust's migration patterns became apparent, governments began to organize crop protection campaigns. Later, it was realized that while locust infestations are concentrated in seasonally restricted areas, their migration can eventually place the entire invasion area at risk. International initiatives followed.

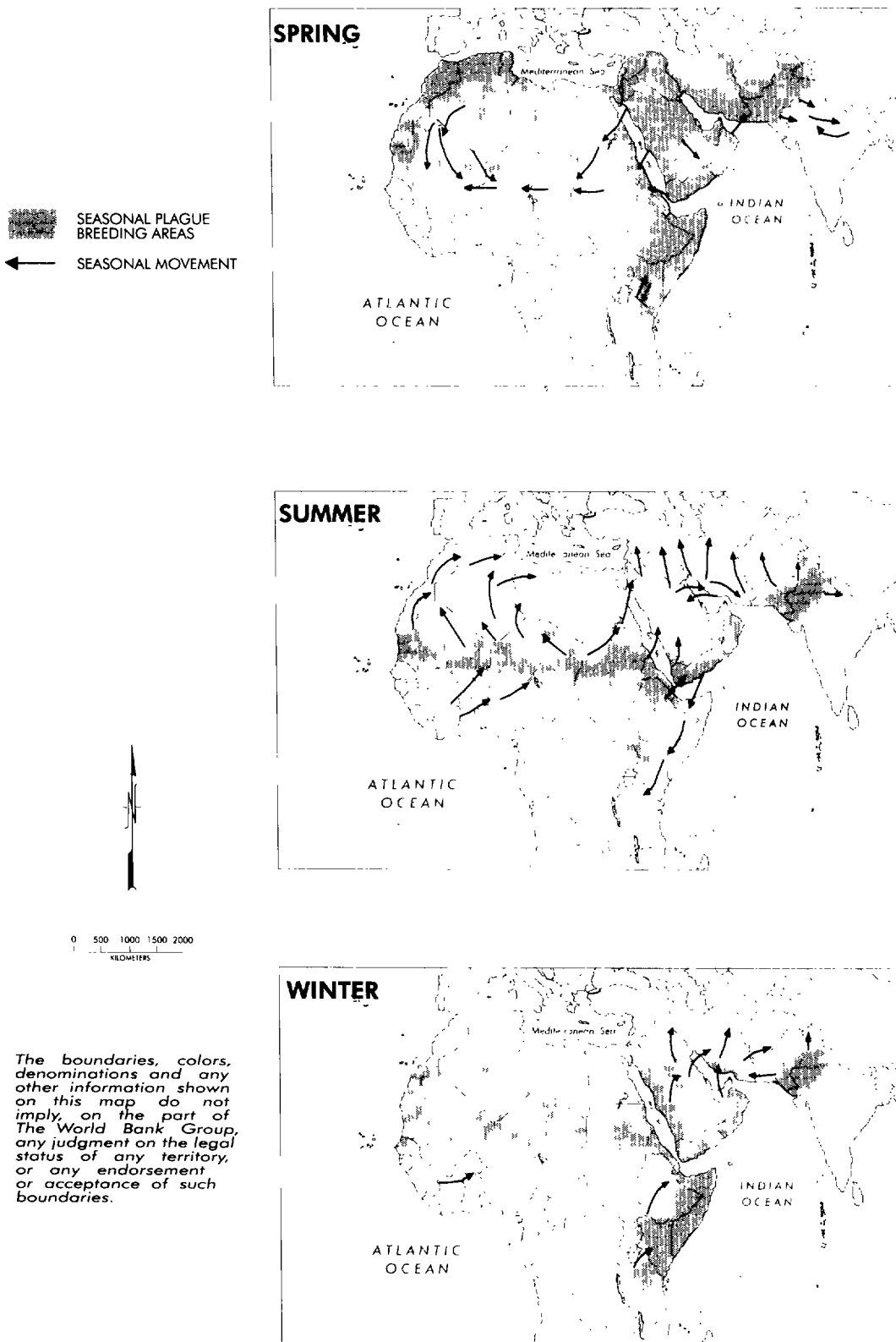
**Strategic Control.** From the 1940s, internationally coordinated control ceased to concentrate solely on crop protection and began to attack locusts wherever possible, no matter how far from cultivation. This early form of strategic control aimed at reducing the population sufficiently for swarms to disperse and for plagues to end.

**Preventive Control** or plague prevention began to be considered a distinctly achievable proposition during the long recessions which characterized the period after 1963. Three approaches have been proposed: outbreak prevention, upsurge prevention and upsurge elimination.

- Outbreak prevention was the original aspiration. Uvarov (1951) considered that the ultimate aim in locust control should be to alter the ecology of outbreak areas so that they no longer could support gregarization (see Box 1). This is not considered to be an option for the Desert Locust. Recently, emphasis has switched to altering locust behavior, e.g. to prevent swarming. This solution is a long term prospect.
- Upsurge prevention, was developed in association with persistent pesticides (organochlorines) and is based on the hypothesis that any outbreak (a gregarizing or gregarious population) could lead to an upsurge. Advocates contend that destroying these initial gregarious populations stops upsurge development and prevents a plague arising.



# AFRICA - SOUTH ASIA DESERT LOCUST SEASONAL PLAGUE BREEDING AREAS



Source: Adapted from Steedman (1988)



- Upsurge elimination involves delay of control until most locusts are gregarious in order to maximize efficiency in terms of kill per unit of insecticide and to minimize the area sprayed. It is based on an analysis of the 1967-69 plague (MacCuaig, 1970). At the beginning of a plague when rainfall is very widespread, locusts spread into numerous areas and gregarized populations are like the tip of an iceberg; most locusts remain in untreatable low densities, spread over large areas. With increased swarming, however, the infested area is dramatically reduced and control is considered more likely to be effective.

**Plague Suppression.** This occurs when an upsurge has become widespread, and swarms become vast and numerous. A major aerial and ground campaign to destroy swarms is undertaken. Efforts are concentrated where the greatest impact on populations can be made. Of necessity, the strategy also involves crop protection activities by farmers and others as gregarious locusts threaten cultivated areas. (Symmons, 1992).

These approaches form a continuum, reflecting numbers and intensity of insect behavior.

## Attempting preventive control

As practiced after the mid-1960s, preventive control involves three steps which may appear sequential, but in practice will often be performed concurrently:

- Monitoring vegetation, rainfall and soil moisture in potential seasonal breeding areas to delimit areas which are suitable for breeding in a specific season (using aerial and ground survey, satellite imagery, weather reports and information from local inhabitants).
- Surveying suitable breeding habitats to establish locust distribution and numbers by teams of experienced local locust scouts.
- Controlling any gregarious or gregarizing locusts. Survey teams may control small infestations but call for help if locust numbers are large.

In 1985 drought broke and despite consultations and plans for preventive control, grasshoppers first, then Desert Locusts and African Migratory, Red, Brown, and Tree Locusts threatened to reach plague proportions by the summer of 1986. FAO called emergency meetings for donors and affected countries and reinstated steering committees for local officials and local representatives of FAO and donors to coordinate aid requests. Creaking infrastructures that had been streamlined during the long recession could not respond to sudden upsurges; institutional memories, which tend to be short, had lost much knowledge hard won in the 1950s and 1960s; retired but experienced personnel and consultants with little or no locust experience came to assist young plant protection specialists facing a plague for the first time. Donors moved from a development stance to the use of emergency funds to address the plague and about US\$324 million were spent on anti-locust activities, mainly for ground and aerial spraying of pesticides, between 1986 and 1989.

Three factors were involved in the plague's rapid collapse in late 1988 and early 1989, but according to evaluations that followed, their relative importance is uncertain:

- Massive pesticide spraying in 1988, particularly in Saudi Arabia and Morocco.
- Large-scale emigration of swarming locusts into the Atlantic Ocean in October and November 1988.
- Failure of breeding due to lack of rains in the winter of 1988/89 and to an unknown cause in the summer of 1989 in the Sahel.

## Box 1. Desert Locust biology and behavior

### What are locusts?

Desert Locusts (*Schistocerca gregaria*) are members of the grasshopper family *Acrididae*. They differ from grasshoppers in their ability to change behavior, color, shape and physiology in response to crowding. Importantly, unlike grasshoppers, Desert Locusts engage in migratory movement of several interconnected seasonal circuits over successive generations on an intercontinental scale. Breeding habitats are also markedly different, with grasshoppers being a chronic pest in agricultural areas, while Desert Locusts usually breed far from cropland and intermittently endanger crops.

### Quick-change insects

Gregarization is the key term that captures locusts' behavior: the shift from solitary behavior to moving in massive units. This change among Desert Locusts is rapid, characterized by increasing mobility and activity: hoppers (nymphs) march and swarms fly, sometimes for long distances, up to 3,000 km in one season. These physical changes in color and shape are so marked that solitary and gregarious forms look like two different species.

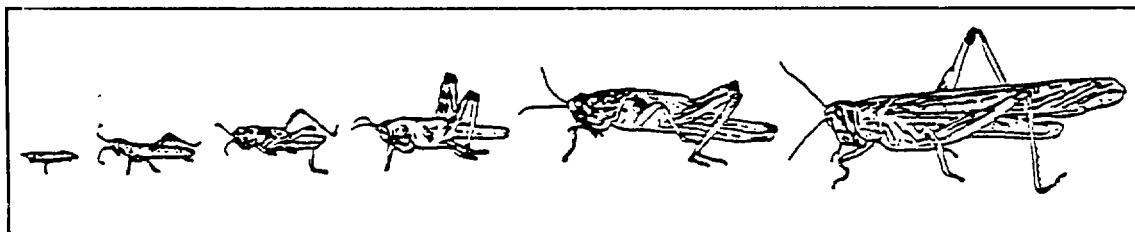
Phase change is a complex mechanism, not yet fully understood. It is likely that pheromones – chemicals used by the insects to signal to each other – are involved. The principal factor which triggers gregarization is density: in the laboratory, species will gregarize as a result of being crowded together when their overall numbers are quite small. In the field, though, non-swarmling locusts show no tendency to crowd voluntarily. What brings them together is a progressive build-up of numbers through breeding and/or through arrivals from elsewhere. This process may be hastened by the drying out of vegetation which causes suitable habitats to gradually shrink in size and locusts to converge on what is available. The process can continue across generations as long as numbers and densities remain high or conversely, the situation can be reversed. Gregarized locusts revert to their solitary state if the swarm breaks up and they become scattered.

### Breeding cycle and migratory pattern

The life cycle of the Desert Locust consists of three stages: eggs, hoppers and adults. Locusts need moist soil for egg-laying; growing hoppers and developing adults need fresh vegetation on which to feed, so the insects are only able to breed during rainy periods. Hoppers periodically shed their skins, usually in five successive growth stages known as "instars." During non-flying stages, the insects may be easiest to control although the biggest challenge is to locate them. The Desert Locust can produce a new generation in about three months. If rains are extensive, more than one generation of locusts can breed in a given area, producing swarms that fly considerable distances to find further suitable breeding conditions. Areas receiving 80-400mm annual rainfall, with a fairly uniform cover of annual grasses with scattered trees, are preferred.

Breeding areas are thus dictated by seasonal rains and the movement of swarms between these areas by prevailing winds. The spring rains fall mainly in North Africa, the Middle East, southern Iran and Pakistan. The resulting swarms then move south and west as these areas dry out, putting Sahelian croplands most at risk. Breeding then takes place during the summer rains in Mauritania, Mali, Niger, Chad, Sudan, Ethiopia and southern Arabia. In Pakistan and India swarms also move southeast to the monsoon rainfall areas. After summer breeding, most swarms tend to move north and northwest. There is a winter breeding season around the Red Sea coasts, which is where historically the majority of plagues have originated. In East Africa, breeding occurs between October and December (the short rains) and from February to June (the long rains).

### Life cycle of Desert Locust over five moltings



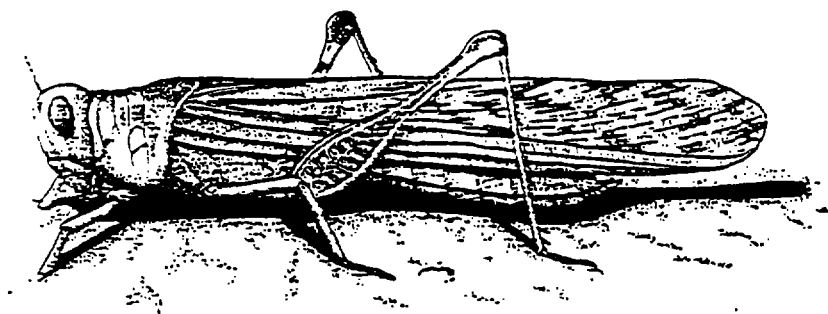
NOTE: Relative sizes of the five instar hoppers and adult Desert Locust, shown at approximately one-half actual size.

SOURCE: A. Steedman, ed., *Locust Handbook* (U.K. Overseas Development Natural Resources Institute, 1988), p.20.



In late 1992, a serious outbreak of the Desert Locust occurred in the Red Sea basin and on the Arabian Peninsular (McCulloch, pers comm). The outbreak rapidly developed into a major upsurge, and although substantial control measures were carried out, there were two major swarm migrations from the region. The first migrated westwards across the Sahel as far as Mauritania where subsequently breeding on a large scale occurred. The second swarm migration led to invasions in India and Pakistan. Control of populations in East Africa, India and Pakistan were considered successful; however, the scale of summer breeding in southern Mauritania was on a substantially larger scale than initially expected. Major control efforts there were unsuccessful, leading to crop infestations in Mauritania and Senegal, and small-scale migrations northwards and southwards before the upsurge ended. By this time about US\$45 million had been spent on chemical control over an area of some 4 million ha.

Fig. 1. The Desert Locust *Schistocerca Gregaria*



More evaluations and proposals followed the 1992-94 upsurge. Observers reiterated that preventive control was handicapped by complacency brought about by the unusually long recession and a number of interrelated factors which decreased efficiency. Importantly, persistent chemicals such as dieldrin (which were relatively cheap and logistically easy to use) had been withdrawn for health and environmental reasons, but strategies had not been over-hauled. Also, many locust organizations -- national, regional, international and donors -- no longer had the people, equipment, funding or administrative mechanisms in place to respond swiftly enough to prevent a locust emergency.

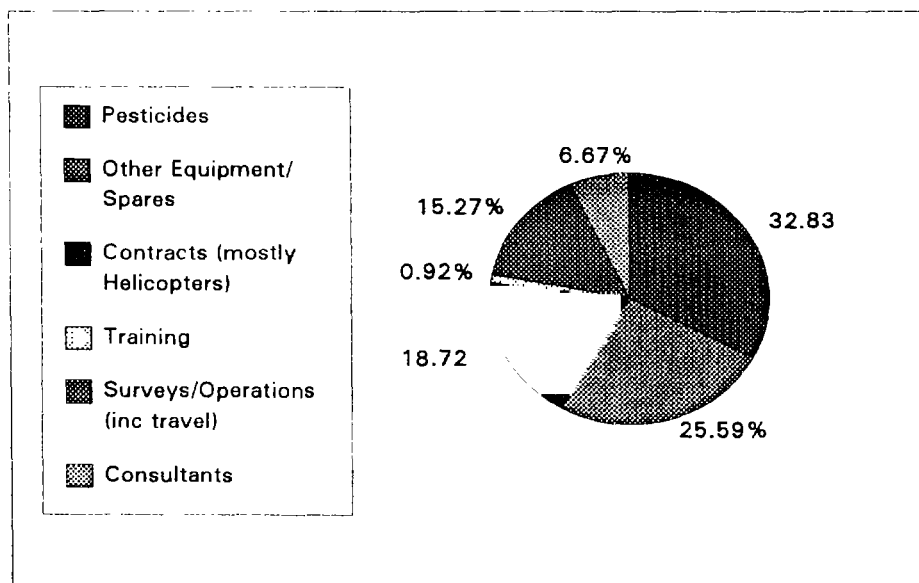
### Survey and control costs

Several analysts (Castleton 1991, Hanley 1989, TAMS 1989, Kremer 1992) have calculated per hectare control costs (both grasshoppers and locusts) from FAO data. Analyses relate mostly to ground control costs; data show similar ULV ground application costs in Senegal (US\$ 5-8.5/ha), Mali (US\$ 8.75 ex air freight) and Mauritania (US\$ 7.57/ha). In 1986-88, 24 million ha were sprayed in the Sahel at an approximate cost of US\$12/ha (CEC, 1992). Overall, costs to donors per hectare are estimated at US\$6-19 in 1986; when local costs are included, the figures rise to US\$15-30 per hectare, "although this expense was exceptional, reflecting the need for rapid emergency mobilization and the air-freighting of formulated insecticides from Europe and the US." (TAMS, 1989).

**Box 2. Lessons learned from Desert Locust control activities: 1928-94**

- Knowledge of insect biology and behavior underpins strategy and control methods.
- Access to all potential breeding areas is a prerequisite to information gathering, hence control.
- Mobility over space and time is essential, necessitating:
  - coverage of the total area - continuous surveillance of potential breeding and treatment areas,
  - ongoing preparedness (expertise, equipment and supplies),
  - flexible structures that can respond to the beginning and end of a plague, and
  - sustainable funding.
- Lack of easy-to apply, safe control methods hinders efficiency and cost-effectiveness.
- Control as a crisis response is costly, inefficient, and may be environmentally damaging.
- Sound institutional arrangements for survey and control have proved elusive. International efforts lack strategic focus; regional organizations are largely moribund, and national plant protection services of many affected countries are weak.
- Donors are reactive rather than cohesive and coordinated regarding strategy, method and funding.
- Political motives and obstacles hinder locust control as a long-term development activity.
- There is no generally accepted control strategy.

During the recent 1992-94 upsurge, the costs to donors for control over nearly 4 million ha were approximately US\$11/ha (McCulloch, pers comm). A breakdown of the \$13 million provided through FAO's Emergency Centre for Locust Operations (ECLO) in the recent upsurge shows that approximately one third was used to procure pesticides:



Recent FAO estimates of costs for surveys and initial early control operations in a range of countries over the summer and winter breeding periods in 1994 appear in Table 1. The considerable variation between countries (from US\$44,000 for Somalia to US\$360,000 for Sudan) is explained by the relative areas involved, the range of operational costs and differing equipment and training needs. In particular, the total survey costs for Sudan as calculated in this instance include the cost of satellite communications and related expenditures.

Participants at a recent meeting at Wageningen Agricultural University (van Huis, 1994b) calculated the relative costs of different control methods to treat an infestation equivalent to 1,200 sq. km of settled swarm. In this simulation exercise (the conclusions of which are not broadly generalizable)

ULV application against individual hopper bands was found to be more expensive than spraying roosted or settled swarms. ULV aerial treatment of settled swarms was found to be better than aerial treatment of flying swarms, on the basis of cost, amount of pesticide used and safety of operators.

**Table 1. FAO estimates of Desert Locust survey and early control costs  
June to December, 1994: eight selected countries (US\$)**

	Chad	Eritrea	Mali	Mauritania	Niger	Somalia	Sudan	Yemen
<b>Operational costs, per team for 30 days<sup>1</sup></b>	4,000	2,000	1,500	4,000	2,000	4,000	4,500	2,000
<b>Total costs over 6 months<sup>2</sup></b>	110,000	157,000	112,000	280,000	96,000	44,000	360,000	131,000

<sup>1</sup> includes: locust officer, technician(s); supervisor, driver(s); mechanic; guide; laborer(s); pilot and engineer where necessary; fuel and maintenance. Wages converted from local currency at UN exchange rate. The composition and number of teams needed differ across countries.

<sup>2</sup> includes: operational costs; equipment (GPS, maps, communications, spare parts); training (field, information systems); technical assistance (survey, training). Six months covers potential Summer and Winter breeding periods.

Source: FAO/ECLC

## Technology for Locust Control

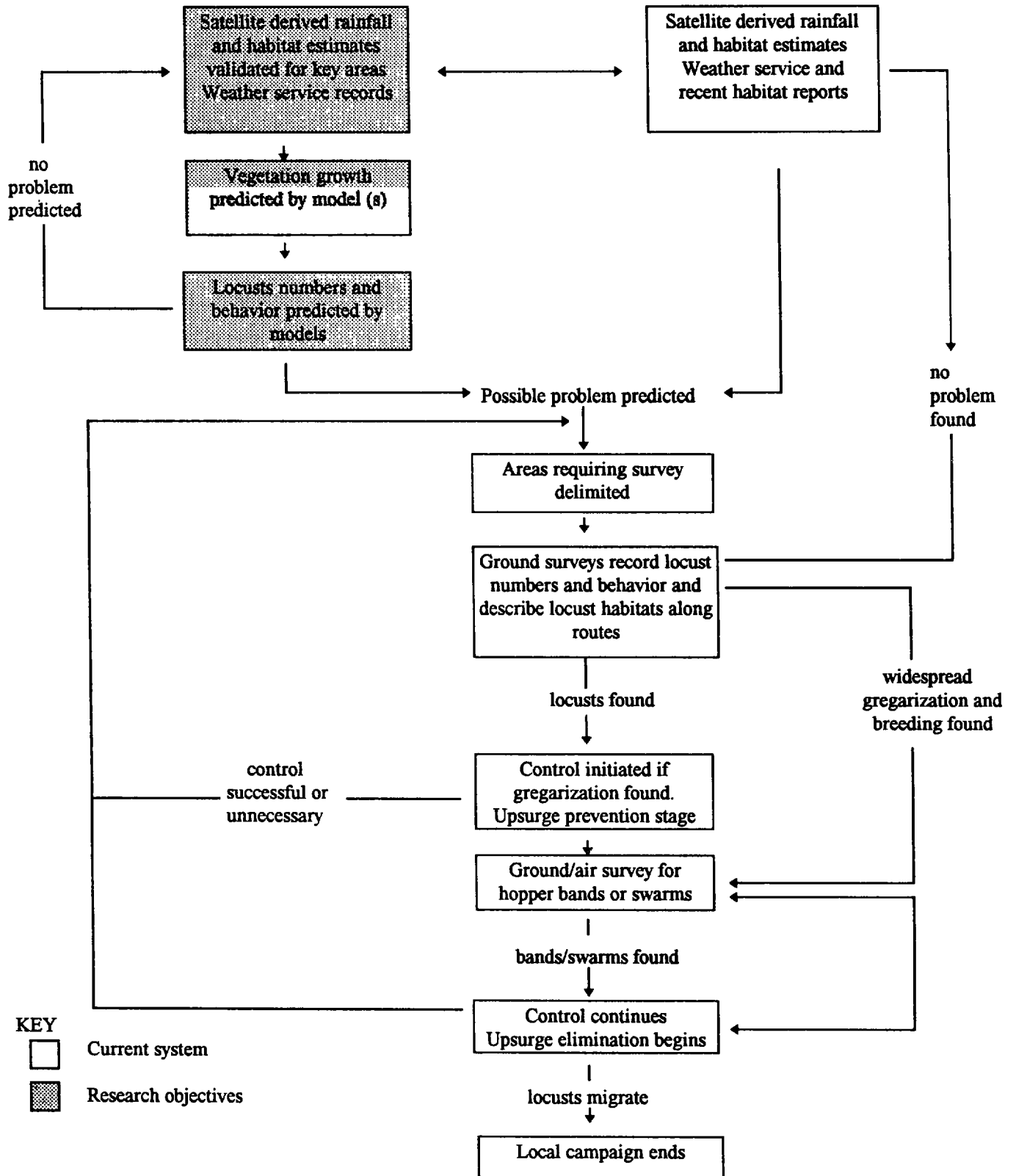
### Finding and forecasting locusts

Current information on locust breeding, density, and phase is the starting point of all locust control operations. Since finding locusts in early breeding sites is an on-the-ground activity, critical data must be gathered and disseminated by local scouts through national plant protection services, then onto regional and/or international units. In most Desert Locust outbreak areas, however, countries lack facilities, competence, experience, and funds to survey (and control) remote areas -- an activity which is just as important in recession periods as during an upsurge. The basic needs are:

- continuous ground and aerial survey of potential locust breeding areas,
- concurrent data on rainfall and vegetation,
- collection, analysis and exchange of locust data across affected countries, and
- capacity for rapid assessment of the need for locust control based on the above.

New forecasting technologies are coming on stream for use in locust control, including satellite imaging for greenness (vegetation) and cold cloud cover. In the final analysis, however, local capacity remains critical. Remote sensing tools are a complement to, but not a substitute for local staff, well-trained in locust control and the ability to generate, use, and interpret forecasts effectively (see Fig. 2).

Fig. 2. Desert Locust forecasting, assessment and early control (after FAO, 1993)



## Chemical control and pesticide choice

Once locust breeding areas are delineated, locust control operations typically consist of a range of chemical control techniques applied on the basis of availability of chemicals, equipment and personnel at remote locations and over a relatively short time span, financed by governments or donors. The window of opportunity for successful control may be as short as a few weeks from first report of infestation. Swarms may invade from neighboring countries or may develop in remote or inaccessible areas. The location and scale of the operation may change abruptly during the campaign and operations frequently cross national boundaries.

Chemical control, the mainstay of current strategy, has superseded various traditional and more labor intensive methods for killing or repelling locusts -- building barriers and digging trenches, burning, beating and smoking the bands and swarms -- because such methods may only be effective against low-level infestations and it is preferable if possible to control locusts before they reach cultivated areas. Effects of traditional practices on the overall locust population, and thus the potential as a preventive or curative strategy will be small. However, locusts often do reach farmers' fields and in the absence of any other technology, farmers have no choice but to try to safeguard some of their crops by traditional methods.

Conventional insecticides used in locust control are generally neurotoxins, with active ingredients divided into four main groups:

- **Organochlorines:** well-known examples are BHC, DDT, dieldrin and endrin which are broad-spectrum and persistent in the environment. Previously the category of choice, organochlorines are now banned by many countries.
- **Organophosphates:** include the two most widely used locust insecticides, fenitrothion and malathion. They are moderately fast-acting (2-8 hrs), relatively non-persistent, but non-selective compounds. Malathion has the advantage of very low mammalian toxicity (WHO class III, slightly hazardous).
- **Synthetic pyrethroids:** examples are *deltamethrin* and *lambda-cyhalothrin*, which are fast-acting ("knock-down" within minutes), varying levels of persistence and broad-spectrum. They are of fairly low mammalian toxicity although some, e.g., deltamethrin, are moderately hazardous.
- **Carbamates:** e.g., bendiocarb, similar in characteristics and action to organophosphates.

Some locust insecticide formulations contain two of the above types of insecticides to exploit the useful characteristics of both. (See Annex 1 for description of common pesticides used for Desert Locust control).

In theory, certain situations suit some of these pesticides better than others. In practice, however, control will be carried out with whichever pesticide is available at the time, mostly made on the basis of cost, rather than criteria. From the procurement stage, donors provide the pesticide of their choice, which may be influenced by national commercial policy (OTA, 1990). Choice of the "wrong" pesticide may be detrimental to effective control.

Other difficulties experienced in chemical control campaigns include: poorly maintained or calibrated application equipment, wrong application techniques applied, adverse meteorological conditions while spraying is carried out and, significantly, the logistics of actually finding and getting to a significant proportion of any medium-to-large infestation.

## Pesticide application techniques and the dieldrin dilemma

The choices in pesticide formulation are four: baits, dusts, emulsifiable concentrate, and ultra-low volume (ULV) spray of oil-based pesticides. Baits and dusts are most likely to be used by farmers. Concentrates require specialized equipment and more careful attention to handling.

Until the 1980s, the technique of choice involved the spraying with barriers of persistent organochlorine insecticides (usually dieldrin) across areas infested by hopper bands. The insects were often killed weeks or months after spraying, by eating vegetation in such barriers; this technique was therefore highly cost-effective. The use of dieldrin was discontinued, however, due to the side-effects on human and animal health and a tendency, not found in non-organochlorine pesticides, to be accumulated in the bodies of animals and become concentrated through food chains. In the absence of dieldrin, other less-persistent pesticides such as fenitrothion or malathion are sprayed or dusted directly onto swarms and hopper bands or distributed as baits. Such control activities are difficult and expensive to mount and are often ineffective in reducing locust numbers due to the difficulty of finding and treating any significant number of existing targets.

The very large quantities of bait formulations required for locust control present logistical problems of manufacture, transport, storage and application in comparison with some other methods. Shelf-life is usually no more than a few weeks. With dusts, again there are logistical problems of supply and application which make use over large areas impractical. Emulsifiable concentrates require water for mixing, a distinct disadvantages in remote and semi-arid areas.

### Box 3. Spray techniques for locust control

ULV spraying can be used in one or more ways simultaneously, depending on locust life-stage (hoppers or swarms), terrain and resources. Techniques include:

**Band spraying** of individual hopper bands by ground or air – pesticide-efficient, but it is very difficult to locate and delineate the bands.

**Block spraying** when surface area is highly infested (say 5%) with hopper bands – rapid, less pesticide-efficient, and more environmental risky due to the large areas covered.

**Barrier spraying** of vegetation strips using persistent chemicals (originally dieldrin) in order to be effective when hoppers arrive and during successive waves of hatching.

**Settled swarm spraying** by ground or air must take place in the relatively short window between dawn and departure of the swarm (requiring swarm location the previous night).

**Flying swarm spraying** has been practiced successfully in the past, but most Desert Locust spray aircraft are not specially equipped to prevent entry of locusts into the air intakes and do not have adequate screen-washing to cope with inevitable accidental encounters with the locusts. It is potentially the most rapid and pesticide-efficient spray strategy (Symmons, 1993), but most pilots will not attempt it because of the dangers.

In the absence of suitable barrier spray products, the speediest and most efficient option involves ground teams or aircraft spraying ULV formulations of a limited range of pesticides onto bands of locust hoppers and settled or flying swarms of adults. The ULV option is now the most widely used method of controlling Desert Locusts and guidelines for its use have been issued by FAO (Symmons, 1993). For large areas, it has been shown to have cost advantages. The disadvantage of ULV spraying are the slightly increased hazard to untrained or ill-equipped operators handling concentrated formulations and the need for special spray equipment (including batteries for hand-held sprayers) and suitable wind conditions. ULV spraying requires good technique for effectiveness -- it must be carried out under the right conditions and using properly calibrated ULV-spraying equipment (i.e., appropriate drop size, emission height, forward speed, track spacing and flow rate); care must be taken that low volumes are deposited fairly uniformly over the target area. On the other hand, water, which may be hard to find, is not required and no mixing of formulations is required. Supply logistics are attractive, with small volumes applied per hectare and a rapid work rate, since wide track spacings can be used (e.g., 100m for an aircraft).

# Institutions

## Past as prologue

Locust control is as old as agriculture, with individual farmers protecting their crops. Organized crop protection campaigns against locusts began in the 1900s, as colonial governments began to grasp the migratory nature of the Desert Locust. The first International Locust Conference took place in Rome in 1920, and during a major plague in 1925-34, many affected governments agreed to collaborate. In the 1930s, an international locust information network and an Anti-Locust Research Centre (ALRC) were established in London; the information network is now maintained by FAO in Rome.

By the 1940s, the United Kingdom established an Interdepartmental Committee on Locust Control, in London, which coordinated and financed locust control as part of the war effort. At about the same time, research and survey activities in a number of West African countries had been assisted by the French government. After the war, locust control organizations were put on a civilian footing. The governments of Egypt, India, Iran and Pakistan continued to maintain permanent anti-locust organizations. Survey and control efforts in countries bordering the Red Sea were continued by Desert Locust Survey, a regional organization whose costs were shared.

## International

### FAO assumes lead

Based on this legacy, FAO became increasingly involved in locust control from 1950 onwards. A Desert Locust Control Committee (DLCC), comprised of all affected countries and interested donors, was established in 1955, with a broad mandate covering coordination of control and research and guidance on national programs. A Technical Advisory Committee (TAC) to DLCC was established; but its functions were eventually taken over by expert panels and consultants before being revived as a Technical Working Group in 1990. In 1969, an FAO Conference established a Working Capital Fund of US\$500,000 and a Panel of Experts on Emergency Action against the Desert Locust and Other Crop Pests. More recently the fund has lapsed and the emergency operation function was brought into FAO proper in 1986 under the Plant Production and Protection Division in Rome.

FAO's mandate of Desert Locust monitoring and overall management was reconfirmed by the UN general assembly in 1988. The primary elements in its operations are the:

- **DLCC** of locust-affected countries and donors (for which FAO provides the secretariat).
  - **DLCC's Technical Working Group** responsible for technical and scientific advice, whose membership is currently drawn from five locust-affected countries.
  - **FAO Regional commissions** in the three important geographic regions of Desert Locust activity: northwest Africa, the Near East, and southwest Asia.
  - **FAO's Locust, Other Migratory Pest and Emergency Operations Group (Migratory Pest Group)** within its Plant Protection Service, a small unit of up to five staff at FAO, Rome responsible for day-to-day operational support. The Migratory Pest Group processes information on pest incidence, issue forecasts, act as the secretariat to the DLCC, and provide assistance to affected countries and regional organizations.
- ECLO (Emergency Center for Locust Operations)**, an administrative mechanism of FAO which is activated at times of major locust upsurges or plagues. It is staffed by the Migratory Pest Group and temporary personnel.

Countries and regional organizations report to FAO on the Desert Locust situation and FAO provides update reports and forecasts to all affected countries, donors and other international institutions. Donors and affected countries depend on FAO for technical advice, information and coordination. Success is highly dependent, therefore, on a strong technical and scientific leadership. An addition to its Technical Working Group, consultants and expert panels (Pesticides Referee Panel, Research Advisory Panel) are also utilized. The Anti-Locust Research Centre ceased to provide direct technical guidance to FAO in the 1980s; the Natural Resources Institute (UK), into which the ALRC was amalgamated, remains a source of expertise, as do other developed country groups such as CIRAD/PRIFAS and Wageningen Agricultural University in the Netherlands.

## **Regional organizations and activities**

During the 1950s, FAO established regional sub-committees for each of the important geopolitical regions associated with Desert Locust migrations (northwest Africa, the Near East, and southwest Asia). These evolved (in 1972, 1969 and 1964, respectively) into FAO Regional Commissions concerned primarily with coordination of joint surveys, control, training and research by member states (see Map: Regional Organizations and FAO Commissions in Charge of Locusts and Grasshopper Control). These regional commissions have headquarters in Tunis, Cairo, and Teheran. Member states<sup>1</sup> finance activities unilaterally and through contributions to a trust fund, set their own policies, and determine survey and control activities. The most active of the commissions is that established by the Maghreb countries (Algeria, Morocco and Tunisia) which, coordinates the activities of a "Force Maghreb."

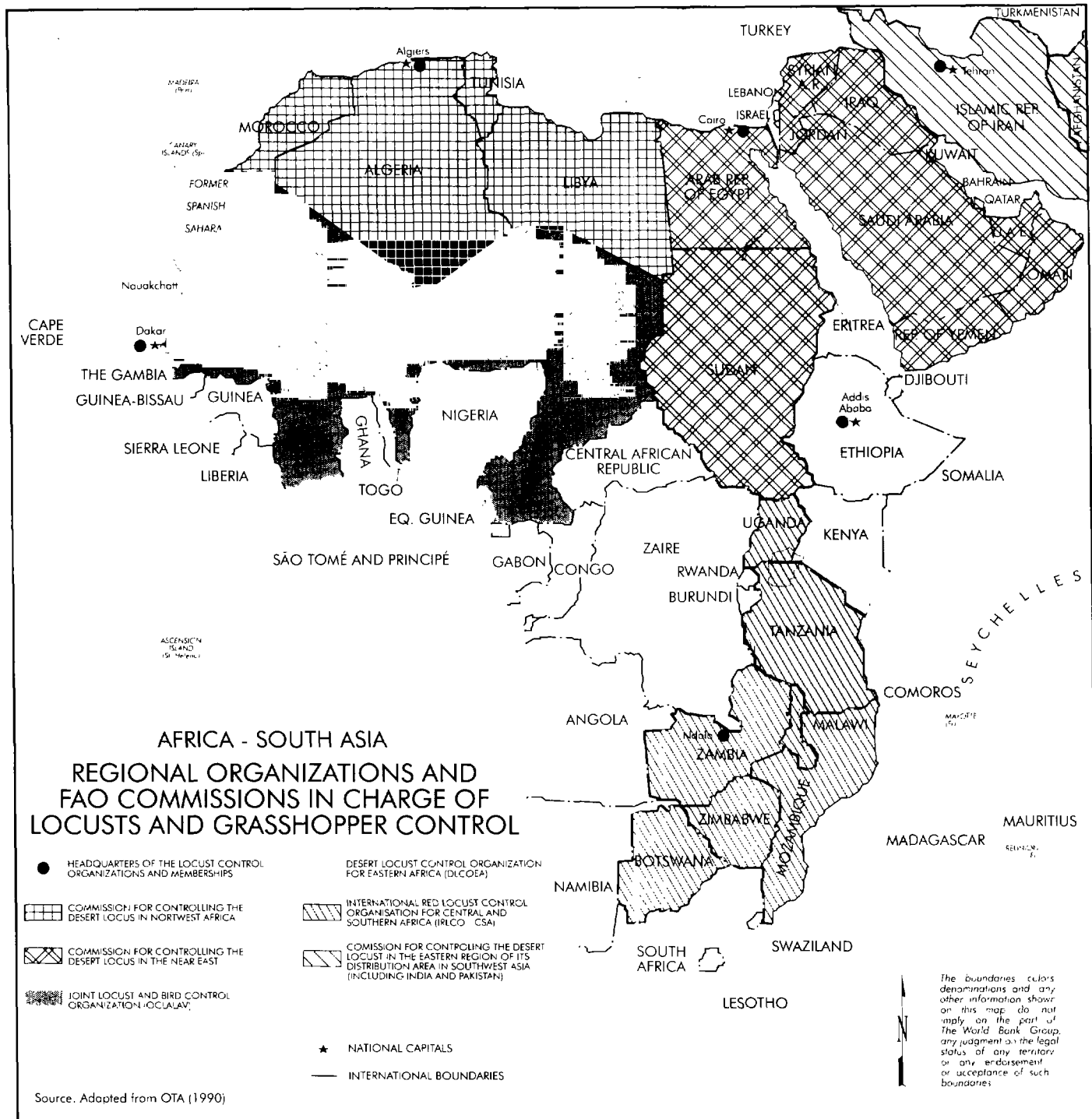
In tandem with FAO's initiatives, autonomous regional organizations for locust control also emerged, initially as offshoots of earlier colonial structures. In East Africa, the Desert Locust Control Organization for Eastern Africa (DLCO-EA) supplements the locust control capacity of its member states (Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan, Tanzania, Uganda), and also has the mandate for the migratory pests: tsetse, *Quelea* and armyworm. DLCO-EA has a staff of approximately 200. Headquarters are in Addis Ababa; it has a substantial facility for aircraft repair and maintenance in Nairobi; research facilities are in Nairobi and Addis Ababa; field bases are in several member countries. Member states have had difficulty in maintaining the estimated US\$2.5 million annual budget; donor contributions are usually restricted only to emergency operations; the organization's effectiveness and operational response capacity are now very limited (McCulloch, pers comm).

Similarly in West Africa, an autonomous Organisation Commune de Lutte Antiacridienne (OCLA) was established in 1958. OCLA became OCLALAV (with the addition of the mandate for control of avian pests such as *Quelea*) but in 1989, its operational mandate and capacity reverted to its member states (Benin, Burkina Faso, Cameroon, Chad, Cote D'Ivoire, the Gambia, Mali, Mauritania, Niger and Senegal), while OCLALAV became a training center and information clearinghouse. In recent years, the CILSS (Inter-State Committee for Drought Control in the Sahel), has provided meteorological information and vegetation greenness maps for the Sahel through AGRHYMET and also has a mandate to strengthen national crop protection through training provided by the DFPV (Department de Formation en Protection des Vegetaux) (Smit, 1992).

---

<sup>1</sup> Membership of the three FAO Regional Commissions is - **Northwest Africa:** Algeria, Libya, Mauritania, Morocco, Tunisia; **the Near East:** Bahrain, Egypt, FDR of Yemen, Iraq, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Sudan, Syria, United Arab Emirates, Yemen; **Southwest Asia:** Afghanistan, India, Iran, Pakistan.







In addition to the formal regional organizations, intraregional cooperation continues between countries whose interests are linked by the seasonal migration routes of the Desert Locust. Thus, for example, India and Pakistan cooperate in Desert Locust management. Algeria and Morocco have cross-border agreements with other members of the northwest Africa Regional Commission as well as with Mali and Niger. The "Force Maghreb" has assisted neighboring countries in the management of upsurges through both field activities and the provision of material assistance including finance and pesticides (McCulloch, pers comm).

## **National plant protection services**

This above-mentioned decline of autonomous regional control organizations has been paralleled by a shift in approach by FAO and UNDP and donors towards strengthening national capacity. In most countries, locust survey and control activities are undertaken by plant protection services under the ministry of agriculture. In some cases, e.g., Algeria, Egypt, India, Morocco, Oman, Pakistan, Saudi Arabia and Sudan, moderate to substantial capacity is in place and these countries generally conduct regular surveys to monitor Desert Locust populations. In other affected countries, the plant protection services remain weak; thus in the key Red Sea winter breeding areas, Eritrea, Ethiopia, Somalia and Yemen have almost no capacity for surveillance and early control. Most Sahelian countries rely heavily on donor assistance to maintain their plant protection services. Priority given to Desert Locust versus other pests, including grasshoppers, tends to be low until an upsurge threatens, and only limited monitoring and reporting may be undertaken.

Activities of the plant protection services are supplemented and supported by information from local meteorological stations (where available), although the availability of remote-sensing data and the flow of information from rural areas in general is restricted by some countries on security grounds. Agricultural research and extension groups participate in the development and adaptation of improved techniques, including collaboration with several donor-funded international research and development (R&D) programs.

When a plague threatens, a number of countries, e.g., Morocco and Algeria (see Box 5), institute rapid response command and coordination functions with interministerial involvement, including an important role for the military. Large numbers of people may be involved. In Morocco some 3,600 people from different government ministries participated in activities between 1987 and 1989 (Mouhim, 1992). The role of village brigades has become popular in several Sahelian countries as a means to mobilize large numbers in crop protection activities. The value of brigades is dependent on a ready supply of free pesticides; it is restricted to areas close to crops and has little practical use in preventive control of the Desert Locust.

## **Donors**

A number of donors support long-term locust R&D programs in addition to emergency control operations (see Box 4). USAID has brought these functions together under the Africa Emergency Locust and Grasshopper Project. ODA's Locust Strategy emphasizes improvement in monitoring, management and forecasting strategies and in control and application technologies; the geographical focus for new ODA supported applied work has recently switched to the important Red Sea breeding areas. Germany supports the GTZ Integrated Biological Control of Grasshoppers and Locusts Project. Several donors, Canada, the Netherlands, Switzerland, the UK and USA, formed a consortium to establish a major CABI/IIBC/IITA/BPC/DFPV biological control of locusts and grasshoppers project. The USA currently supports a separate biological control project (employing a different fungal species) executed by Montana State University in collaboration with Mycotech Inc.). The same donors and others regularly exchange information via less-formal contacts.

#### Box 4. Financing Desert Locust control

Locust-affected countries finance Desert Locust survey and control operations through national budgets, FAO trust funds and, primarily, through international grants and loans.

Data on national expenditures are limited. It is clear that there is a considerable range in the ability to pay for survey and control operations. The governments of Morocco, Algeria and Tunisia budgeted US\$76 million, US\$58 million<sup>1</sup> and US\$10 million, respectively, in 1989, in order to protect high-value citrus and other crops (OTA, 1990). The governments of India and Pakistan, where the Desert Locust invasion area overlaps with areas of irrigated production, regularly finance 100% of Desert Locust survey and control operations, although donor assistance is sought following swarm invasions, as in 1993 (Magor, pers comm). Saudi Arabia is assumed to commit substantial sums to survey and control. In contrast Mali, Senegal, Somalia, and Sudan contributed an estimated US\$1-4 million each during the 1986-89 plague.

Donor emergency funds flow through direct bilateral and multilateral channels, with FAO often the coordinating mechanism in the latter case. Major bilateral donors in recent years are Canada, France, Germany, Japan, The Netherlands, UK and USA. Significant multilateral donors have been FAO itself, as well as the African Development Bank, European Community, Islamic Development Bank, UNDP and the World Bank (through assistance to Algeria). A number of international NGOs, have also made significant contributions.

Between 1986 and 1994, donors provided more than US\$383 million for locust and grasshopper control. Most funds were extended on grant terms, the exception being agreed World Bank loans totaling US\$88 million to Algeria<sup>2</sup> and US\$2 million to Cameroon. The bulk of expenditure was made during the 1986-89 plague (US\$324 million). During 1993-94 upsurge approximately US\$42-45 million have been spent on emergency control.

Disaggregation of grasshopper and locusts control efforts is difficult. During the 1986-89 campaign a significant proportion of funds were used to control upsurges of Senegalese Grasshopper (*Oedaleus senegalensis*), however FAO estimates that twice as much area was treated against Desert Locusts as against grasshoppers (Gruys, 1992). During the 1993-94 upsurge control efforts were largely directed at Desert Locusts.

Also, not all donor support went to countries affected by the Desert Locust. Approximately 16% of the total support between 1986 and 1994 went to control of locusts and grasshoppers in countries outside of the Desert Locust invasion area; for example Red Locust in Southern Africa, or African Migratory locust control in Madagascar.

An increasing trend in donor financing is to support regional control initiatives. During 1986-89, regional funding, including support for OCLALAV and DLCO-EA, was about 8% of the total; in 1993-94 the proportion rises to 35%.

1. This amount was committed to an Algeria/World Bank project agreed in 1993. Most of the Bank's contribution was not disbursed as the substantial expected threat did not materialize. It is assumed that Algeria costs were also substantially less than the US\$58 million originally committed.
2. The loans to Algeria were US\$58 million in 1988 and US\$30 million in 1993, of which only US\$22 million and US\$2 million, respectively, have been disbursed (see above). The US\$2 million loan to Cameroon was not disbursed.

In 1989, the Scientific Advisory Committee (SAC) was established by an informal Consultative Group on Locust Research (CGLR), and jointly chaired by UNDP and FAO. UNDP has used the CGLR/SAC mechanism as a source of advice on its locust program, the Development of Environmentally Acceptable Alternative Strategies for Desert Locust Control (1990-94). A research project on Desert Locust semiochemicals at ICIPE, supported by IFAD, SAREC and the Arab Fund, used the CGLR/SAC for advice and project evaluation. This research coordinating mechanism has not been sustained by donors and is now winding down (Zelazny, pers comm); a review has been circulated for consideration.

## Box 5. How Algeria organizes locust control<sup>1</sup>

Algeria has established laws and decrees aimed at allowing the government to take urgent action should an invasion of Desert Locusts occur. (Locust invasions are classified as one of 14 natural disasters likely to threaten the country.)

During recession periods, locust control is the responsibility of the National Institute for Plant Protection (INPV) in the Ministry of Agriculture. In times of minor upsurges, locusts are controlled by the Locust Control Unit within INPV. The monitoring and control function in recession periods is linked to plant protection services provided on a permanent basis. Government strategy is to respond to a declared emergency by mobilizing the necessary resources, both human and material, from existing sources rather than to create a permanent structure.

When plague threatens, the Interministerial Locust Control Committee (CILA) is activated. The CILA was created on August 31, 1967 and includes the ministries for defense, transportation, foreign affairs, interior, agriculture, finance and planning, industry and energy, and telecommunications. At the central level, CILA becomes the principal policy making body for locust control operations. Its mandate is to define locust prevention and control strategy, to monitor implementation of the operational plans adopted, and to coordinate locust control activities at the ministerial level.

The Central Command Post (PCC), the executing body of the CILA, manages locust control campaigns during plague situations. Its Director reports directly to the Minister of Agriculture and to the CILA. The PCC plays a key coordinating role by disseminating control strategies and operational plans to the provinces, by providing information to the regional commission and to neighboring countries, and by liaising with regional organizations; the FAO provides coordination at the international level. Three operational units within PCC provide: (i) technical support through the provision of technical assistance to the provinces when necessary; (ii) logistical support through management of the central resource base (pesticides, commercial aircraft services, vehicles and equipment); and (iii) management and financial support. Once activated, the PCC is staffed with INPV personnel that are temporarily assigned to the locust control effort.

Both INPV and PCC work closely with the National Meteorological Services which releases important information for the tracking and predicting of locust activity. INPV/PCC also liaises with: (a) the National Agency for the Protection of the Environment (ANPE) which monitors industrial pollution including the use of pesticides; and (b) the National Agency for the Conservation of Nature (ANN) which is responsible for the national parks as well as for the preservation of the country's assets of natural resources. The Ministry of Health is another important partner, to ensure that the operators handling pesticides are adequately protected and treated should any misuse of chemicals occur.

At the wilaya level a Wilaya Command Post (PCW), is activated, whose President is the Governor. Depending on the severity of the locust situation, a technical unit is created within the PCW, headed by the local chief of the Division for the Department of Hydraulics and Agriculture. The PCW, through its technical unit, implements wilaya-level operational plans, and is mandated to mobilize all the necessary resources. An elaborate communication system keeps the PCC in radio contact with the PCWs, as well as with the mobile prospecting units in the field.

---

<sup>1</sup> Based on institutional arrangements discussed in the context of the Algeria/World Bank Emergency Desert Locust Control Project 1993.

**Table 2. Donor assistance to locust and grasshopper control programs, 1986 - 1994 (US\$ million)**

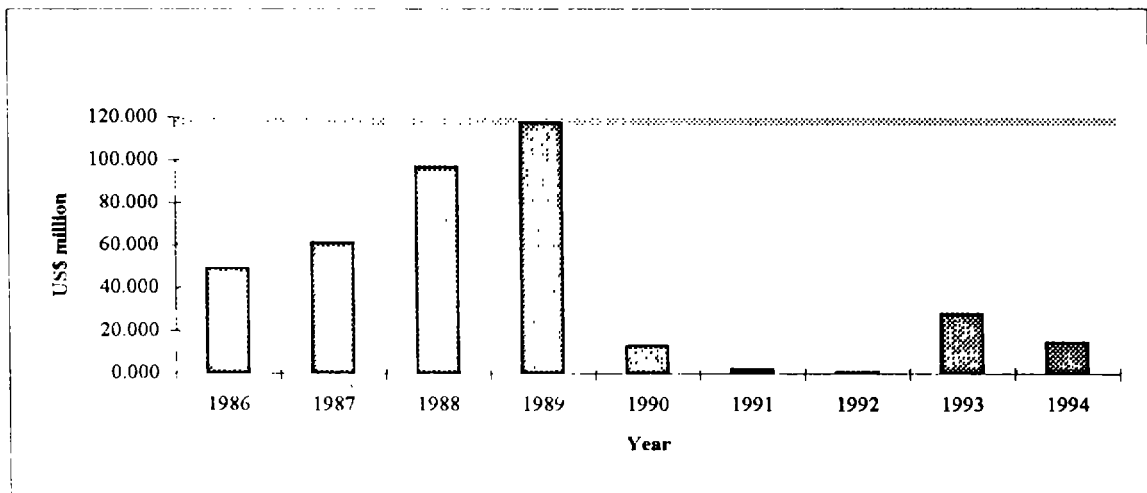
Region	1986	1987	1988	1989	1990	1991	1992	1993	1994	1986-94
North Africa	0.000	1.108	31.678	47.941	0.000	0.000	0.000	1.808	0.904	83.440
Sahel/W. Africa	30.652	35.509	35.648	42.646	10.541	2.000	0.460	14.418	7.209	179.085
South Asia	0.000	1.486	2.257	1.672	0.000	0.000	0.000	3.280	1.888	10.583
Eastern Africa	10.777	8.023	12.493	11.780	0.106	0.000	0.000	3.781	2.062	49.023
Other	7.456	15.187	14.810	13.341	2.511	0.000	0.190	4.706	2.355	60.557
<b>TOTAL</b>	<b>48.885</b>	<b>61.314</b>	<b>96.887</b>	<b>117.380</b>	<b>13.158</b>	<b>2.000</b>	<b>0.650</b>	<b>27.995</b>	<b>14.418</b>	<b>382.687</b>

Includes multilateral assistance through FAO and bilateral assistance as reported to FAO.

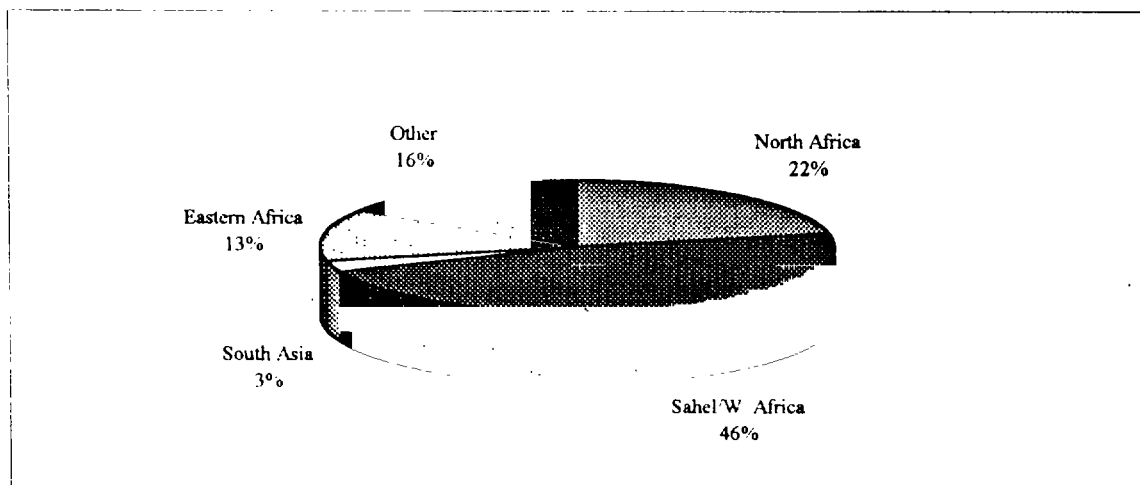
North Africa 1989, includes World Bank \$22 million disbursement of loan to Algeria. 1991 -94 includes "in kind" assistance. Figures for 1993 and 1994 are from total figures for the current emergency apportioned 2/3:1/3 between 1993 and 1994.

Sources: Gruys (1990); FAO-DLCC (1990, 1992); World Bank, Algeria (1993)

**Fig. 3. Donor assistance to locust & grasshopper control, 1986-94**



**Fig. 4. Regional breakdown of locust & grasshopper assistance, 1986-94**



# ISSUES

## Incomplete Rationale for Control

Underlying locust control are long-standing assumptions regarding the seriousness and nature of damage caused by locust invasions. Recently, observers have questioned these assumptions (OTA, 1990, Krall, 1994), but donors continue to fund emergency operations, without apparently confronting the issues raised. Plans and operations are carried forward with minimum recourse to economic or social impact analysis either before or after the event.

### Limited damage estimates

A major constraint on estimating impact is that data on locust damage are scant and inconsistently derived. The information in Table 3 originates primarily from two comprehensive multi-country surveys of affected countries following major plagues during 1925-34 and 1949-58. A limited 1990 survey by the US Office of Technology Assessment did not include crop loss data. No other comprehensive assessments have been undertaken. The recent data (since 1988) originate primarily from field missions undertaken by USAID and FAO personnel. There are no quantitative data available to date from evaluations of the 1992-1994 upsurge (Balanca and de Visscheer, 1994).

What data there are suggest that Desert Locusts are not a particularly serious pest in aggregate. Crop losses caused by locusts at a national level, and across time, are generally small compared to losses caused by other pests. Estimates of the potential losses to an uncontrolled Desert Locust upsurge (e.g. Bullen, 1972, Brader, 1989) do not exceed 5% of production in any given year. Research in the Sahelian rainfed sorghum and millet belt suggests that grasshoppers in general, including *Oedaleus senegalensis* and *Kraussaria angulifera* cause more regular and chronic crop losses than do locusts (Coop and Croft, 1993, Jago et. al., 1993). In the Sahel farmers have problems with millet head-miner, millet stem-borer, scarabeid beetles, various meloid beetles, birds, fungal pathogens, weeds (especially *Striga* spp). Overall the available data suggest that Sahelian farmers may be losing on average as much as 50% of potential small grain yields to insect pests (Jago, ed., 1993).

### Nature of impacts

Major Locust outbreaks occur, by definition, in years of higher than average rainfall, the most important influence on grain yields in rainfed agriculture. Mali's production of coarse grains in 1985-86 (a year of locust and grasshopper outbreaks) was up 44% on the previous year; after another good harvest the next year, coarse grain prices on local markets collapsed and the rural poor benefited as net buyers of cereals (USAID, 1993). Concomitant with the 1993 Desert Locust outbreak, record harvests were forecast for Burkina Faso, Mauritania and Senegal, above average harvest for Niger and about average for Mali and Chad (FAO, 1993). As the Desert Locust upsurge continued through into 1994, food markets in west Africa were reported to be well supplied following generally above average harvests in 1993, the exception being some areas of Chad and Niger.

In reality, with a highly mobile pest such as the Desert Locust, the rationale driving control measures is not so much the absolute level of damage likely, but the concern over where, and to whom, any damage will be inflicted. Aggregate data can mask severe local damage; thus, in 1954-55, 90% of reported damage was localized in the Souss valley of Southern Morocco where some US\$4 million of commercial orange production was lost; in 1958, virtually all the recorded damage occurred in the Tigray

and Wollo areas of Ethiopia where locusts and a disease epidemic triggered severe localized food shortages following failure of the rains in the previous year (Webb et. al., 1992).

These two examples highlight well the two principle types of impact from a Desert Locust infestation that cause concern. Desert Locusts are unlikely in modern times to trigger widespread food insecurity, however, they could cause localized problems where communities are already vulnerable. In other contexts, the threat to commercial agriculture is a more important factor. In the Maghreb, mixed irrigated and rainfed cropping systems plus substantial commercial export production can be jeopardized; fruit exports alone of the Maghreb countries were worth approximately US\$590 million in 1992. Easterly spring invasions and summer breeding may threaten wheat, rice, cotton and sugarcane in the southern and northern irrigated plains of Pakistan, as well as very important irrigated cropping systems in India's Punjab and Haryana. These countries finance effective national programs for locust control (see Box 4).

### **Politics over analysis**

Given the paucity of data on the economics of Desert Locust control, little in the way of cost benefit analysis is possible. Where cost benefit analysis has been applied, the outcome is marginal. Analysis by the USAID Famine Early Warning System (FEWS, 1987) of locust and grasshopper control efforts in nine African countries during 1986 yielded a marginal overall net return of around 1.1:1. The US Office of Technology Assessment concludes that "the cost-effectiveness of the locust and grasshopper control programs has not been demonstrated...and there is evidence that other problems may have a greater potential for each dollar of development aid spent" (OTA, 1990). Outcomes regarding specific Desert Locust initiatives may be weaker still. A recent GTZ analysis (Krall, 1994) casts further doubt over the economic returns to large-scale locust operations in rainfed agricultural systems of Africa.

It appears that political pressure to intervene with control measures against Desert Locusts has overtaken considerations of economic and environmental analysis or of long-term measures to mitigate risks for those affected (see Box 6). Governments of affected countries face pressure to take action; locusts are a highly visible nuisance when they reach urban areas; in agricultural areas their status as pests is elevated by the unpredictable nature of impacts and the potential for locally severe effects. The emotive nature of locust swarms also ensures a strong public response in donor countries. These factors tend to exaggerate the importance of Desert Locusts beyond that which appears to be justified by the impact data and analyses available.

Currently donors rely on FAO's Migratory Pest Group, guided by the Desert Locust Control Committee and its Technical Working Group, to advise them on needs. The political temperature of these fora at times of a major locust upsurge can be high, and the lack of objective, high-quality technical and policy-oriented advice has been noted by several commentators in recent years.

To assist regions, including some of the poorest agricultural economies, to counter or avoid large-scale locust invasions is understandable. However, it is reasonable and necessary to review the extent to which such assistance is consistent with the level and nature of expected impacts. Means to assess impacts and to target interventions against needs are required, but are not currently available. There are no initiatives underway to develop such means "since the control strategy for the Desert Locust is population containment and control operations are conducted irrespective of actual or expected damage" (Gruys, 1992).



**Table 3. Estimates of crop losses caused by Desert Locusts, 1925-89**

All figures are based on subjective estimates and need to be treated with caution. Data relate specifically to the Desert Locust, as far is known, unless stated otherwise.

Year	Country	Crop Loss/Damage Estimate (Pounds Sterling) <sup>1</sup>	1990 Value (US\$ million) <sup>2</sup>
1925-34	Plague <sup>3</sup>	10 countries	various crops: 442,000 per year
1925-34	India	various crops: 141,000 per year	
1925-34	Morocco	various crops: 98,000 per year	
1925-34	Kenya	various crops: 80,000 per year	
1944	Libya	19% of all grapevines	
1949-58	Plague	26 countries <sup>4</sup>	various crops: 2.1 million per year
1953	Somalia	various crops: 600,000 per year	
1954	Sudan	55,000 MT of grain	7.33 <sup>5</sup>
1954-55	Morocco	7,000 MT oranges	3.91
1957	Senegal	16,000 MT of millet 2,000 MT of other crops	2.68
1957	Guinea	6,000 MT of oranges	3.35
1958	Ethiopia	167,000 MT of grain	20.91 <sup>6</sup>
1962	India	4,000 ha of cotton	0.69 <sup>7</sup>
1986-89	all countries	insignificant damage overall	
1988	Sudan	2% of cereals production	13.67 <sup>8</sup>
	Mali	2% of cereals production	6.61 <sup>9</sup>

<sup>1</sup> figures, where available, are as originally reported in pounds sterling.

<sup>2</sup> 1990 figures obtained by using "international \$" price and converted at: 1 "international \$" = US\$1 (see Prasada Rao, 1993); oranges are valued at 1990, France, for average price Moroccan; and cotton at 1990, Liverpool CIF, SM 1-1/16 US Memphis

<sup>3</sup> average annual loss to species including the Desert Locust reported by 10 recipients of a 49 country survey.

<sup>4</sup> 26 out of 40 countries responded to an FAO survey.

<sup>5</sup> valued at international \$ price of sorghum

<sup>6</sup> valued at mean international \$ price of maize, barley and sorghum

<sup>7</sup> valued at the average 1962 India yield of 93 kg/ha (A.F. Ferguson & Co (1994), vol. II, appendix 1, schedule 2)

<sup>8</sup> FAO 1988 cereal production statistics and valued at international \$ price for sorghum

<sup>9</sup> FAO 1988 cereal production statistics and valued at mean international \$ price for sorghum and millet

Sources: (Bullen, 1972); (OTA, 1990); (Prasada Rao, 1993); (Rowley, 1993); (Showler, 1994); (Steedman Ed., 1988); (Uvarov and Bowman, 1938) and *FAO Production Year Book, 1993*.

## Lack of Effective Strategy

In practice, no single strategy is pursued to control Desert Locusts; when upsurge prevention fails; upsurge elimination is attempted, and then plague suppression. When preventive control fails, and effective contingency plans are not in place, a Desert Locust emergency results. The financing of control campaigns is problematic; at present locust control emergency campaigns are resourced primarily through emergency grants to the affected countries, including substantial contributions of pesticides, vehicles and equipment. This situation is widely acknowledged to be untenable. It leads to a misallocation of resources towards unsustainable pest management practices and policies, encourages inefficient use of

resources, creates incentives to exaggerate or falsify locust outbreaks, and substantially elevates both direct and indirect costs.

## **Preparedness needed**

**Preparedness.** At the onset of both the 1986-89 plague and the 1992-94 upsurge, a lack of preparedness on all parts substantially hindered effective actions. In the former case, it is clear that the long recession period led to the run-down of surveillance, and to complacency; in the latter case this excuse should not have to be made; preliminary evaluations (e.g., McCulloch, pers comm; Wilps, 1994) point, among other factors, to lack of surveys and of critical information flow; late or inaccurate forecasts (due in part to understaffing at FAO/ECLC); slow and bureaucratic responses by donors and a lack of consistency in donor programs; lack of trained personnel in-country; poor organization and resourcing of campaigns in the field; lack of proper environmental and safety monitoring, and lack of field evaluation of control measures.

In the latest upsurge, arrival of Desert Locust swarms in Mauritania in July occurred nine months after evidence of a possible significant upsurge in the central Red Sea breeding area, yet was still a surprise. Few if any preparations had been made. 'Emergency' control operations began in November, a full year after the initial outbreak. Some 850,000 ha of land were sprayed with pesticides at a cost of more than US\$14 million, yet these actions were both avoidable and largely ineffective (Wilps, 1994).

## **Is upsurge prevention viable?**

Moving from an emergency to a long-term basis for Desert Locust management is necessary, but there is no consensus on how this should be done. One area where expert opinion diverges concerns the possibility of preventing an upsurge from occurring at all - upsurge prevention. The balance of opinion suggests that this may be a flawed strategy for the time being at least, for three principal reasons:

**Technical limitations.** Destroying initially gregarious populations may well leave sufficient non-swarmling populations to continue the upsurge. Data from Van Huis (1994) indicate that most bands of every generation must be sprayed and high rates of kill achieved (80-90%) to prevent population increases to plague levels. Gruys (1994 in press), MacCuaig (1970) Courshee (1990) and Symmons (1992) argue that this kill rate is unlikely to be achieved at the very early stages of an upsurge as is often implicitly assumed, in the absence of an effective, persistent control agent. Such an approach also contrasts with guidelines by FAO consultants (FAO, 1985), indicating that small swarms and large pre-gregarious populations could be left uncontrolled unless in cropping areas.

Plausible evidence exists to show that only when most locusts are in sprayable targets can population be effectively reduced. This occurs when upsurges are well developed and in the course of plagues. It follows from this view that contingency planning should extend from the onset of unusually heavy and prolonged rains to the stage where most locusts are gregarious and when moderate invasions totaling about 1000 sq. km of swarms must be expected. An approach based predominantly on swarm control has been suggested (Symmons, 1992). This technical strategy assumes that upsurge prevention is unlikely to be successful, and concentrates instead on early warning systems, contingency plans and elimination or suppression of upsurges once well developed.

**Environmental-economic concerns.** Upsurge prevention requires the treatment of large areas containing initially gregarizing populations based on hopper band control; hopper bands occupy only 1-5% of suitable habitats and are difficult to find; finding and treating individual bands takes too long to be effective; alternatively, blanket-spraying entire areas increases economic and environmental costs further. The costs of these operations in both direct and indirect terms (environmental impacts) will accrue whether or not a significant upsurge is likely.

## Box 6. Agricultural policy: program response to risk from Desert Locusts

Agriculture is risky, especially so in marginal semi-arid environments favored by the Desert Locust. There are several options open to governments and donors to counter food sector instability in general which would reduce the adverse impacts of any localized production shortfalls caused by these pests. Instability in production creates food insecurity only to the extent that it destabilizes or reduces people's real (subsistence or cash) incomes and access to food: variations in local production need not destabilize food availability and prices if trade, processing, or storage can be used to integrate markets geographically, across products, or over time (USAID, 1993). In the Sahel as other parts of Africa the lack of such integration is frequently caused by high trading costs, itself associated with poor infrastructure and market information flows, weak regulatory and financial institutions and restrictive government policies.

In the broadest terms Anderson and Dillon (1992) point out that *ipso facto* productivity growth has the benefit of providing insurance against risk. Thus a commitment to accelerate the agricultural growth rate in affected semi-arid countries, allied to broad-based rural productivity growth will reduce the real and perceived importance of locusts. More specifically, a continued commitment to the gradual and phased, liberalization of food and input marketing at all levels will be a key stabilizing measure. Investments in rural roads, market information systems, and appropriate grades and standards, will serve to reduce marketing costs. Identification and support for diverse farm level risk-mitigation institutions, ranging from informal reciprocal arrangements to explicit contractual arrangements, and generally, the development of freely functioning rural financial markets, also has a significant role in helping farmers to meet risks (Anderson and Dillon, 1992). A more contentious issue is the role that food aid can have. Efficient use of food aid can help to stabilize supplies and prices (USAID, 1993). In the context of a localized shortfall caused by locusts, the targeted support necessary would have high administration costs; however there is some potential for support through local NGO-managed labor-intensive food-for-work schemes.

Improved response to and preparedness for Desert Locust invasions could be developed under the umbrella of a National Disaster Prevention and Preparedness Strategy (DPSS) such as that developed by Ethiopia following famine periods in the 1980's (Webb et al, 1992). The principal components of the Ethiopia DPSS are commitments toward (1) emergency legislation designed to delegate responsibilities and speed up responses to crises; (2) institution-building to strengthen the planning and response capacities of relevant government organizations; (3) investment in enhanced information systems (to guide the appropriate crisis response) and; (4) preparation of interventions to enhance institutional readiness for action. All of these components are relevant to Desert Locust management.

Given the inherently unpredictable nature of locust impacts and the low overall probability of an individual farmer or village being affected, crop insurance is an obvious means in principle to mitigate the risks (Hazell et al., 1986). In practice, high operating costs and premiums would render formal public or private insurance schemes impractical in the context of locusts threatening semi-arid farming systems (Anderson and Dillon 1992), where assistance towards community level, informal risk mitigation measures has better potential. This is not necessarily the case in the countries where high-value agriculture (citrus plantations, almonds, dates, olives, vegetables, grapevines, irrigated cotton and sugarcane) is threatened. The potential for insurance schemes to mitigate risks of locust attack should be explored. Public funded schemes rarely operate without subsidy; private/informal schemes may have more potential but in many countries would require parallel policy changes.

<sup>1</sup> A number of examples of insurance schemes are identified by Gudger (1991) in areas which may be affected by locusts (including Red Locust and Migratory Locust); Kenya (tea, export flowers, tree crops, vegetables); Zambia (maize); South Africa (30 crops); Sudan and Egypt (cotton); Morocco and Tunisia (unspecified); Israel (unspecified); Jordan (vegetables); Pakistan (livestock); Turkey (grains and vegetables); Mauritius, while it does not have a locust problem, apparently has a 'model scheme' for insuring its sugar crop.

Waiting until most locusts are gregarious and then pursuing upsurge elimination, would reduce the area of target population to be sprayed, but still requires substantial areas to be searched to find much sprayable targets of hopper bands and swarms. In principle a policy of targeted swarm control alone would be more efficient, use less pesticide and pollute less land, since the locusts are concentrated into smaller areas. In the course of plagues efforts can be concentrated in areas where locusts swarms tend to accumulate and where access is relatively easy; these areas are known.

**Institution and financing shortfalls.** To be successful, upsurge prevention, indeed any strategy relying on effective early intervention, requires sustainable recurrent financing to provide institutions with

an efficient information and forecasting network and a sufficiently flexible control capacity to cover the rapid augmentation of personnel, vehicles, equipment and pesticide required when upsurges occur. This capacity is not uniformly available among countries of the recession areas; also, important potential outbreak areas continue to be inaccessible through border disputes.

Bringing to bear the necessary coverage of the recession areas to make upsurge prevention a realistic prospect would require the strengthening of anti-locust control capacity in all relevant countries. However, for many of the countries concerned there is no sound economic justification for such investments, nor is it likely that the recurrent financing of operations could be sustained by governments of the affected countries.

On the assumption that upsurge prevention cannot be relied upon, it is likely that further major upsurges and plagues will occur. These do not happen overnight and there is little justification for a policy of emergency response by donors. Instead, the scope for and means of improving preparedness based on contingency planning and the adoption of some universally accepted action thresholds, is now essential. (See Box 7 for USAID's intervention thresholds.)

#### **Box 7. USAID's intervention thresholds for locust control**

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 50,000-300,000 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 gregarize 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 US\$10 million.

In making specific decisions about needed level of support, USAID recognizes the need to exercise restraint, given that over the past few years, the use of pesticides has been gradually increasing.

### **Can Desert Locust Control be Based on an IPM Strategy?**

The Bank and many others (e.g., TAMS, 1989; OTA, 1990; USAID, 1991) consider placement of Desert Locust control within the context of integrated pest management (IPM) a desirable goal. Development of an IPM-based strategy against the Desert Locust would involve moving away from an approach which seeks to suppress the Desert Locust population as a whole to one that keeps the impacts of a locust upsurge within economically, socially, and environmentally acceptable limits. There are scenarios, for example, where the economic case for Desert Locust control would be relatively strong, in particular where large areas of high-value agriculture or at-risk subsistence economies would be affected. However, there are currently limitations to the extent that different control decisions, including 'no

control', can be evaluated in economic terms: only a very basic action threshold exists in the sense that solitary locusts are not targeted, whereas gregarious locusts are. A number of constraints on data, methods and technologies need to be addressed.

### **Research gaps**

**Population dynamics.** IPM stresses the need for an understanding of pest population dynamics and its interaction with control activities. There remain large gaps in the knowledge required to develop useful models. The DGIS Wageningen seminar (van Huis, 1994b) attempted to simulate such interactions based on assumed population levels derived from expert opinion. Although such simulations cannot predict where future upsurges could be expected (because of the complexity of locust biology, the imprecision of long-range weather forecasting and the political inaccessibility of some areas to ground survey teams), they do enable comparisons of theoretical population responses to different control options. This should indicate, for example, whether control efforts should be limited to areas of locust concentration (south of the Atlas mountains in Algeria and Morocco, the Red Sea coast and the Tihama of Arabia) as has been suggested by some experts (van Huis, 1994a).

**Probability of locust attack in a given production systems.** Forecasting remains an imprecise art. At present standard FAO forecast bulletins predict the absence or presence of locusts, either scattered or in bands or swarms, within a particular district of a country, over a six-week period; the scale and area of any infestation is indicated in relative terms such as 'few', 'many', or 'heavy'. The likelihood of breeding is predicted and the timing, direction and possible destination of any out-migrations, again by district. Forecasts are not always accurate; an evaluation of forecast locust movements from July-November 1989 indicated 42-50% accuracy; the greatest single activity under-forecast was that swarms turned up in unexpected places (Cressman, pers comm). To complicate matters further, the presence of locusts in an agricultural area, even adult swarms, is not sufficient to indicate that crop damage will take place. If conditions are unfavorable, e.g. in terms of temperature or humidity, there may be little feeding activity.

**Crop loss.** The effects of locust attack on growth and yield are complex and variable, resulting from the interaction of the pest's feeding behavior, its density and distribution within the crop, and the timing of attack in relation to plant growth (seedling and milky grain stage are most vulnerable stages for cereals, Wright, 1986). Locust feeding behavior and damage caused are not uniform or predictable (Uvarov, 1977). Losses may vary substantially between and even within individual fields (Jago et al., 1993). The final loss in yield may be substantially less than initial damage would suggest, due to regrowth, compensation, or re-sowing by farmers. These problems are complex, but protocols for systematic crop loss assessments do exist and have been used, for example, to assess losses to locusts in Australia. Methods for grasshoppers and other pests of millet could be adapted for use. A problem is the high costs that would be involved in a systematic exercise of quantitative crop loss assessment in the often remote areas threatened by Desert Locusts; for example a proposal for Desert Locust crop loss assessments in Morocco and Mali, costed at up to US\$3 million, was rejected by the FAO in 1989 (Gruys, 1992). More cost-effective rapid assessment methodologies for damage assessment, and the institutional capacity to undertake such assessments, are clearly needed to obtain better data on impacts; lack of evaluation of impacts of locust infestations by FAO and other donors or research to support this objective needs to be urgently reviewed.

**Impacts of Lost Production.** For food crops, especially those largely consumed on-farm, the impact of lost production is complex. Prices of food crops at key local markets in the Sahel are regularly monitored by the USAID Famine Early Warning System (FEWS, 1992), the FAO Global Information and Early Warning System (FAO-GIEWS) and other groups, as is information on crops and planted areas that could be utilized in a predictive risk assessment. These are useful data, but not enough to identify groups likely to be most at risk from a locust attack. FEWS have established monitoring systems that allow the identification of vulnerable groups based on a series of long and short-term indicators, including those based on prices, stocks and production statistics and forecasts, pasture quality, household assets and

reserves, remote-sensing of rainfall and vegetation (NDVI and METEOSAT), transhumance information, qualitative reports and others. It is striking that the level of resolution of the information provided is very similar to that in FAO's Desert Locust Bulletins; also that both use the same remote-sensing products and rely on regular ground surveys. The FAO-GIEWS does include reports of locust activity in its assessments of possible production shortfalls and food security situations in developing countries (e.g., FAO 1993b, 1994a). However, the reciprocal does not appear to be true, i.e., that information on the food security status of different countries or regions does not figure in the decision framework for Desert Locust control.

**Alternative control agents.** Available alternative locust control methods are a crucial limiting factor to IPM programs. The newer control techniques under development may eventually permit a more varied and appropriate response to locust problems in different situations (see Box 8). Appropriate formulation of biopesticides may in the future result in greater persistence, leading to much greater efficiency; this would be necessary if they are to find use in barrier spraying against hoppers. In some cases, mixtures of slow-acting and "knock-down" approaches may be combined. Novel approaches to formulation may extend field persistence of conventional pesticides and could reduce mammalian and aquatic toxicity (Jepson, 1993). Field testing of mycopesticides (fungal spores) is beginning and will intensify, probably leading to the availability of effective products within 5-10 years. Usable semiochemical control techniques applicable to the Desert Locust seem to be further off. It seems unlikely that current research could yield exploitable technology within much less than 10 years. With adequate coordination and political will, IGR (insect growth regulator) insecticide formulations could be tested and registered for use in barrier spraying within three years.

It is likely therefore that the major method of management of the Desert Locust for the next three years at least will probably remain chemical control with organophosphate, carbamate and pyrethroid insecticides. Until alternatives become available, it remains a goal of IPM to minimize and rationalize pesticide use, based on the best available techno-economic and environmental analysis, and to ensure that necessary applications are made as effectively as possible (TAMS, 1989). There is certainly scope for improvement to the implementation of current control technologies which will result in immediate economic, environmental and human safety benefits in addition to more reliable locust control efficacy.

## How to Safeguard the Environment?

### Sources of risk

Chemical control of locusts has caused substantial concern over health and environmental impacts (to humans, animals, birds, invertebrates and soil microorganisms), and whether these are justifiable considering the lack of evidence that chemical control is effective in ending plagues. Concern was triggered by the use of persistent organochlorine insecticides (including dieldrin and BHC), which break down slowly in the environment and can be accumulated in the human food chain. Dieldrin was withdrawn from use in the United States in 1974 and subsequently worldwide, though left-over stocks continue to be used. More recently, the scale of pesticide use against locust and grasshoppers has aggravated concern. During the 1986-89 plague, 14 million kg of pesticide dust and 16 million liters of liquid formulations were applied (Greenpeace International & The Pesticide Trust, 1993).

A major programmatic environmental assessment on locust and grasshopper control in Africa and Asia has been conducted for USAID (TAMS, 1989) and a review of environmental concerns was issued by USAID (1991). More effective and safer methods have been the subject, *inter alia*, of an FAO workshop in Morocco and an international seminar at Wageningen Agricultural University, both in 1993.

Recurring problems with all pesticides include inappropriate storage, handling, transport and application. Also, vested interests may obscure difficulties; for example, contract pilots not wanting to admit they have applied the wrong dose, or units not admitting that the activity of a pesticide is low due to poor storage. Detailed analysis of practices and problems is needed to identify appropriate equipment, techniques and training requirements of the locust-affected countries.

Substantial concentrations of out-of-date or banned pesticides exist in parts of the Desert Locust area; an estimated minimum of 6,500 metric tons of obsolete pesticides are stored in Africa and the Middle East, of which the largest part consists of organochlorine compounds. The most serious spillage to date occurred when the DLCO-EA Main Operational Base at Hargeisa, Somalia, was bombed and looted during the civil war in 1988 (Lambert, 1993). In the process more than 81,200 liters of organochlorine and organophosphate insecticides were released into the environment.

These pesticides were acquired, often with donor assistance, for control of a variety of pests including locusts. Their safe disposal should be a major concern to donor agencies involved in locust control. They will likely continue to be used for emergency locust control when stocks of less-damaging alternatives have been exhausted, as happened in Tunisia in 1988 when shortage of other compounds led to the application of BHC dust (Potter & Showler, 1991) and dieldrin by air and ground in uninhabited areas near the Indo-Pakistan border in 1993.

## **Mitigating actions**

**Prepare national control policy.** There is a clear need for decision-making tools and checklists for impact assessment of locust control operations based on accumulated knowledge of the ecotoxicological hazard posed by each product, known exposure risks and a greatly increased knowledge of the function and diversity of semi-arid ecosystems in locust-affected areas of Africa and the Middle East. These elements of hazard information for individual chemicals and site-specific environmental assessment need to be combined with detailed operating procedures and incorporated into national control policies.

For USAID, Gruys (1991) proposed that a sound national control policy should be a basic condition for future funding of control operations based on preparation of national control policy statements detailing such matters as control strategy, pesticide management plans, training programs, and environmental impact mitigation measures. Regional organizations and FAO were put forward as logical sources of help to prepare such statements.

**Find alternatives to current chemicals.** Potential alternatives to conventional control include insect growth regulators (IGRs) which interfere with locust molting. Barrier sprayed using ULV, these may be persistent enough to replace dieldrin as an economical control method for hopper bands, with minimal impact on the environment. Field trials against Desert Locust are urgently needed if these compounds are to be brought into use within three years. Among the biological control methods proposed for locust control are mycopesticides, oil-based formulations of fungal spores that are pathogenic to locusts. These are unlikely to be available for operational use before five years. Other proposed techniques, including use of semiochemicals (or biorationals) seek to alter insect behavior or maturation and are unlikely to offer useful products within 10 years. (See Box 8).

**Remove obsolete pesticide stocks and improve procurement procedures.** Technology exists to destroy unwanted pesticides using high temperature incineration (up to 1600 degrees C). However, it would be necessary for major agencies to organize and underwrite the costs of this, roughly estimated at US\$5,000 per ton, including repacking, shipping to Europe, and incineration. Several donors, notably GTZ, have already assisted developing countries with disposal of unwanted dieldrin stocks, mostly by incineration in Europe.

## Box 8. Potential alternatives to current methods of Desert Locust control

### Insect growth regulators (IGRs)

Insect growth regulators prevent nymphs from successfully molting. They are showing promise, but have not yet been tested in large-scale operational trials. IGRs open the door to a new control strategy, or more accurately, a return to something like the old dieldrin strategy based on barrier spraying. They are persistent on vegetation, yet exhibit low vertebrate toxicity and thus have the potential to perform in a similar way to dieldrin, but without undesirable side effects.

No large-scale field trials of IGRs were mounted against Desert Locust during 1986-89 or 1993-94. This may be partly due to the understandable reluctance of affected countries to mount experimental control trials during an emergency against large hopper band infestations.

### Pathogens (mycopensticides)

Fungi are among the most frequently reported pathogens of locusts. Research centers on development of mycopensticides using spores of the fungi, which can be formulated in oil as a ULV spray for use in place of insecticides. As yet, there has not been a definitive test of any fungal pathogen against field populations of the Desert Locust. Current optimism is based on encouraging results with locusts in field cages in Niger and small plot trials against grasshoppers in Benin (Bateman, 1993), as well as small-scale field tests against other locust species in Madagascar, South Africa, and Australia.

Using biopesticides involves all the current problems of conventional insecticide spraying: finding the locusts, communicating their whereabouts, supply logistics for inputs, reaching them and spraying them properly at the right time. Additional difficulties are the slow action of mycopensticides and the need to reach the hoppers at an early instar stage with protozoan parasites. As such, they can only be as good as, or worse than, conventional insecticides in controlling locusts. However, if they are effective, environmental benefits may justify their choice.

### Biorationals

Biorationals include semiochemicals of plant or insect origin (or synthetic analogues) which exercise behavioral or physiological effects on the target insect. Research has begun on a wide range of semiochemicals and other novel approaches, of which the more significant are:

- antifeedants such as the neem tree (*Azadirachta indica*) extract, which causes developmental abnormalities, leading to some degree of solitarization of treated gregarized hoppers (Langewald and Schmutterer, 1992).
- juvenile hormone analogues (JHAs) that disrupt the sexual maturation. More than 2,000 insect JHAs are known and some are under examination as potential control agents (Krall & Nasseh, 1992).
- pheromones, being investigated for their potential in modifying behavior and development of locusts with the aim of disrupting the process of gregarization (Raina, 1992).

If any of these chemicals proves to exercise a dominant role in any important physiological or behavioral process they may be usable in control.

### Control by insects and other natural enemies

There are many natural enemies of *Schistocerca gregaria*, including vertebrate and invertebrate predators, insect parasitoids, parasitic nematodes and pathogens (Greathead, 1962; 1992). These predators and parasitoids play a small role in regulating locust populations because they are, despite some documented exceptions, unable to follow swarms to the next breeding area (Uvarov, 1977). They may hasten the end of plagues but do not prevent upsurges (Greathead, 1992).

FAO is in the process of establishing a project on the Prevention and Disposal of Unwanted Pesticide Stocks in Africa and the Near East to coordinate disposal activities, set up a working group of interested donors, establish an inventory of obsolete stocks, and develop guidelines on tender for the procurement of pesticides. These guidelines will assist donors and recipients to avoid accumulating unnecessary stocks.

Used pesticide drums are extremely difficult to clean and attempts to wash them produce contaminated waste needing disposal. Some suppliers are moving towards provision of an internal removable liner for drums which will reduce contamination problems (USAID, 1991).



**Set up a pesticide bank.** During the 1986-89 plague, international "pesticide bank" schemes were operated by the European Union and USAID. In practice this involves agreements among potential users to share a common pool of pesticides, either by bilateral or multilateral agreements between the users themselves, or by centralizing the 'bank' with an organization such as the European Union. Pesticide banks help prevent the buildup of excess pesticides within affected 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 (Showler, 1994).

**Avoid protected and critical habitats and migrant birds.** All countries within the Desert Locust area contain areas of land or water of special conservation value which may or may not be the subject of national protective legislation. For protected areas an inventory has been prepared (IUCN, 1992). Such areas should be avoided in locust-spraying operations, and buffer zones of 2.5 km should be established around them (TAMS, 1989).

Migrant birds from Europe traverse the Sahara to reach overwintering areas in western, eastern and southern Africa. Migration routes are complex and nearly 170 individual maps were used to prepare a simplified scheme showing two major movements via Morocco and the Sahelian countries in West Africa and via the Red Sea coast and Ethiopia in East Africa (TAMS, 1989). Many of these birds are insect feeders and will gorge themselves on large numbers of Desert Locust. The use of malathion rather than fenitrothion would greatly reduce risk to birds.

**Use and apply insecticides correctly.** Most adverse side-effects of spraying can be avoided by adherence to FAO application guidelines and careful choice of insecticides. Regular training courses for spray operators and other locust control personnel in survey, pesticide safety, ULV application, storage and handling of pesticides and campaign management are essential, and control personnel need to have access to necessary transport, ULV spray gear, spares and ancillary equipment if they are to achieve effective control while minimizing pesticide use. Whichever the pesticide or habitat, overdosing represents an unnecessary environmental challenge, yet it was reported as one of the most significant environmental factors in the 1994 Desert Locust campaign in Senegal (Van der Valk, pers comm), pointing to the overriding need for training of technicians and operators in application techniques.

**Improve targeting through aerial spraying operations.** New navigation technology for aircraft and ground teams has potential for improving locust control operations. Global positioning systems (GPS) are now relatively cheap (US\$500-1000) and can give an accurate position fix anywhere in the world. This is an invaluable tool when combined with good radio communications for calling aircraft to locust spray targets.

**Improve operator protection and training.** Regular training and rigorous application of standards in relation to maintenance, protective clothing, labeling and procedures for decanting and mixing pesticides must be followed if control staff are to remain safe. It is essential that disposable face masks and gloves, visors, loose cotton overalls or "pajamas" and rubber boots are provided for operators and worn by them. Adequate facilities for washing themselves and their clothes must be provided.

**Monitor environmental effects of locust spraying.** Almost any spraying campaign against locust involves non-target effects. However, during the 1986-89 plague, few monitoring or ecotoxicological monitoring studies were undertaken (Gruys, 1992). This made evaluation of circumstantial reports of deaths of non-target organisms impossible. Several experimental studies of the effects of locust and grasshopper spraying have been carried out in Mali by American and Norwegian teams (Dynamac, 1988; Johannessen, 1991; Otteson, et al., 1989; Otteson and Somme, 1989; Krokene, 1993; Fiskvatn, 1993). FAO commissioned an environmental assessment of aerial spraying with fenitrothion against locusts in Sudan (Pinto et al., 1988), and in 1989, with funding from DGIS, Netherlands, conducted a pilot study of the environmental effects of locust and grasshopper control (Everts, 1990), which developed into an ecotoxicological research program in Senegal (the LOCUSTOX

Project) to determine the level of residues from locust control operations and to assess their effects on non-target fauna.

### **Box 9. Assessing environmental impacts of locust control activities**

Most development agencies including the World Bank concur (e.g. IBRD 1991b) that locust control normally requires environmental assessment as part of standard procedure for proposed projects. Beyond project-level assessment, similar criteria may be applied to sectoral or regional activities, which is the arena for most locust control operations.

A case in point is the "programmatic" environmental assessment for locust control in Africa for USAID (TAMS, 1989); for example, it cited 32 recommendations to mitigate environmental concerns including environmentally sensitive areas of all locust-affected countries. "Preparing an inventory of environmentally sensitive areas; prohibiting spraying in human settlements and environmentally fragile areas; selecting pesticides with the least impact on non-target species; monitoring selected organisms, and soil and water for pesticide residues; supplementing control techniques with a strong technical assistance component; assisting countries in disposal of obsolete pesticides; testing biological control in the field; and providing training and equipment." (IBRD, 1991a).

These recommendations remain as valid now as they were five years ago. Some of the required actions are proceeding but there is still a pressing need to prepare national inventories. The expense in most cases will be small since the affected countries will already be reviewing such areas in fulfillment of their responsibilities under the terms of the Biodiversity Convention.

While USAID stipulates such a prior evaluation of pesticide use, regulations can be suspended during an emergency—as they were during 1986-89. Nonetheless in the context of national programs, USAID has prepared supplementary environmental assessments on locust control for Burkina Faso, Chad, Cameroon, Madagascar, Mali, Mauritania, Niger and Senegal. These documents review USAID regulatory structures and existing relevant national legislation and provide a short national environmental profile and other baseline data relevant to the locust problem. In the case of the Madagascar (USAID, 1992), it goes on to define thresholds for intervention and a broad strategic approach to the problem and set standards for pesticide safety. Critical habitats are described and pesticide use prohibited in them. Subsequently an amendment was issued (Belayneh, 1993) covering the use of the IGR diflufenzuron (dimilin) for locust and grasshopper control in Madagascar.

Gruys (1992), commenting on the earlier studies, noted that the inputs of funding and effort required to conduct field studies on environmental impact are substantial and the results often disappointing. He instanced lack of knowledge of the ecosystems involved, difficulties in identifying indicator species and adequate sample sizes for statistical analysis as problems and noted that studies were generally short-term, measuring acute effects and unable to address long-term effects on the ecosystem function. The LOCUSTOX project has an important role in training personnel from locust-affected countries and developing appropriate techniques.

A major problem of impact assessment studies in the context of actual control operations is the short period available for baseline data collection. This makes inferences based on before/after comparisons questionable because of unknown seasonal effects. At the same time, environmental heterogeneity makes simultaneous sprayed/unsprayed comparisons equally difficult. Increasing effort is being put into the development of monitoring techniques for environmental impact of control operations by the FAO LOCUSTOX project and other groups.

## **Lack of data and information flow**

Most functions necessary to effective and safe locust control depend on vital, on-site information. Notwithstanding the advances in remote-sensing technologies (see Box 10) local scouts are still essential - both to initiate awareness and to confirm locust breeding and density. Effective surveillance and monitoring depends on reliable data, skillful analysis, and technology to transmit information on an ongoing basis. These components, including the requisite two-way communication between field sites, national centers and regional or international clearinghouses, are often weak or absent. The same problems are experienced during control campaigns.

## Box 10. Satellite imaging and modeling of locust behavior

Several initiatives are underway to develop improved means to assess and forecast Desert Locust activity using data from METEOSAT (cold cloud cover indicating likely rainfall) and NOAA satellites, using a normalized difference vegetation index (NDVI) (indicating likely suitable breeding conditions).

Sustained aid, largely from the Netherlands, has led to FAO's development of the African Real-Time Environmental Monitoring and Information System (ARTEMIS), an operational satellite imagery system for estimating rainfall and vegetation indices for locust forecasting and famine early warning systems. As its name implies, it does not supply information on areas in Oman and southwest Asia where Desert Locust upsurges can also start. Recently, with Belgian funds, an improved system was developed for identifying sparse vegetation found in Desert Locust outbreak areas in one region of the Sahel. Importantly, these products need to be combined with locust surveys so that population development correlations with vegetation indices can be calibrated. Low-cost satellite receiving systems are now available to provide customized products for a variety of uses and are being supplied by donors to national and regional bodies.

FAO's RAMSES (Reconnaissance and Management System of the Environment of *Schistocerca* (Desert Locust)) is a proposed umbrella project to develop enhanced remote-sensing and modeling techniques and integrate these through a geographic information system (GIS). The system will utilize remote sensing data, combined with models of vegetation and locust behavior, to predict the sites of locust breeding and subsequent upsurges. If successful, ground and air control crews could be better targeted and operations based on threshold criteria, financial and environmental costs would be reduced and prospects for preventive control of locusts should be enhanced. RAMSES will also incorporate data on the distribution of important cropping areas so that forecasters will be able to pay special attention to the potential of those areas being invaded (FAO, 1993).

UNDP has financed the production of a new GIS monitoring, forecasting and investigative tool to manage the administration, mapping and analysis of past and present locust weather and habitat data. The system, SWARMS (Schistocerca WARNING and Management System), imports weather charts and remote-sensing products from other computer systems and allow spatial data from these different sources to be overlaid on a range of background maps at varying scales. A complementary UK-funded project is determining and costing the methodological and technical developments needed to provide modellers with information from the GIS to calibrate their models – as a step toward investigating alternative control strategies and their impact on the environment. GIS designers and modellers ensured its compatibility with a migration model developed in the Netherlands (METEOCONSULT) and with FAO's new remote-sensing products. It is hoped that a French-funded GIS, formulated after discussion with FAO and its GIS designers, will build on the FAO system.

Mathematical models have also been developed to attempt to predict the development of locust populations. Again, the importance of raw data from local ground surveys from remote areas by trained scouts cannot be overemphasized, since cold cloud does not always mean rain and favorable conditions will not produce breeding without locusts. In practice, these raw data are often lacking. The descriptive Desert Locust bio-model, developed by PRIFAS, with French Ministry of Cooperation and Development, CIRAD/PRIFAS and EC funding, though not strictly a simulation model, predicts population size, behavior and movements to assess developments of unreported or partially reported populations. The effect of weather on locust, populations, is mediated through environment variables (geomorphology, soils, drainage, vegetation) in these areas.

The current control strategy is to find and control gregarious locusts, but finding gregarious locusts is difficult to do. Fielding expert locust control teams in remote conditions is never easy, and less so in the face of low priority given to locusts due to their intermittent threat, budgetary shortfalls, and lack of training, transport, and communications equipment. Aerial technology alone is not sufficient. From the air, bands may or may not be visible, depending on their stage and the vegetation or soil they are on. It is unlikely that any significant proportion of hopper bands in a large infestation could be individually treated, or even located. Swarms are easier to spot from further away, but the problems of getting to them and treating them before they fly away are greater.

Security difficulties or simple shortage of vehicles or fuel may prevent survey teams entering zones where conditions are favorable for locusts. Organizations may be unwilling to pass on information

which might reflect unfavorably on them or may wish to conceal the absence of good quality information. Security concerns may further impede data transmission; for example, many locust-affected countries are reluctant to allow use of satellite-based communications due to security considerations. The use of **portable telephones, modems, and hand-held data-loggers** that could be a major advantage in data collection and locust monitoring, may be illegal.

Data need to be well-managed to allow sound control decisions to be made -- where, when, how. For local applications, geographic information systems (GIS) are showing some promise in this regard. They can now be processed by personal computers, but training difficulties (involving a fairly steep learning curve) and local hardware and software maintenance need to be addressed. At the international level, greater sharing and compatibility need to be achieved across systems (e.g., FAO GIEWS and USAID FEWS) that monitor the same or similar zones for different data.

Effective control operations require a communication and support structure to ensure that operational teams do not run out of essentials such as pesticides, fuel and spare parts. In many cases, **organizations lack the communications network to service operations effectively.** Constraints include lack of training and experience of logistics, as well as lack of communication equipment, and lack of spare parts.

So, while the technology and information systems needed for data transmission, management, and assessment of Desert Locusts are available at increased quality, lower cost and greater access, they are not fully taken advantage of, due to civil and military insecurity, low national priority, lack of operational funds and lack of training.

Improvement to locust surveillance, monitoring and control is to a large extent dependent on better communication links, both vertically -- engaging local scouts, national plant protection services, international and regional organizations -- and horizontally across affected states and regions. Key points for attention are:

- Cross border access across all affected areas by field scouts and control teams
- Accurate field reporting from critical sites, which shift with locust activity.
- Low-cost information technology at the local level that can link up with all international monitoring and reporting facilities.
- Better international sharing of data relevant to locust control.

## **Ineffective Action and International Coordination**

### **Disparate national capacity and response**

Effective Desert Locust management necessarily starts with the commitment, policies and actions of the countries affected. Yet considerable variation occurs in the economic status and agricultural systems of countries affected by the Desert Locust both within the permanent recession area and within the potential invasion area. The degree of risk from locust invasions varies, as does the economic pest status of the Desert Locust, according to the areas and values of production at risk (see Table 4).

The national priority given to continual surveillance of key locust and breeding sites, and to early control measures, depends on the costs of taking action in relation to available resources versus the **perceived risk associated with not doing so.** Some countries undertake surveys and early control (often in collaboration with like-minded neighbors and in areas that are relatively well-defined) to ensure against possible losses to important high-value crops, and strongly urge other countries to do the same. For other countries, the costs of such actions (especially across vast territories where key sites are usually poorly

researched) cannot be justified in the face of competing priorities; the social consequences of this inactivity can occasionally be high but a call for emergency assistance will usually be followed by international action and donations.

In the face of such different stakes and opportunities for effective action, the problem for the international community is that the actions of one country or group of countries can affect the outcomes of a locust upsurge for neighboring countries or even those thousands of miles away. Clearly, individual national strategies should be developed within an overall agreed set of regional/international objectives in Desert Locust management, and certain minimal monitoring activities identified as essential rather than discretionary.

## **Management and oversight**

International Desert Locust control campaigns have been undertaken under UN/FAO oversight for more than 40 years, and some US\$383 million has been committed to Desert Locust control (including World Bank loans) over the past 10 years alone. It is reasonable to expect substantial progress towards the short- and long-term measures needed to manage this pest, roles identified for different stakeholders, a broadly agreed strategy, including R&D requirements, in place, balancing overall resources against the probability of further outbreaks and the impact, socio-economic and environmental associated with such outbreaks and their control. In reality, little progress is apparent. The lack of long-term planning, combined with short institutional memories at all levels, ensures that the available systems and resources are overwhelmed each time an outbreak occurs. There are several key constraints:

### **Inconsistent programs and approach**

During recent upsurges there has been an apparent mismatch between the resources and technical assistance needed for effective locust management and their supply by donors. Most assistance flowed directly through country-specific bilateral programs and much of this was not reported to FAO. It is questionable whether this approach to resourcing emergency operations can be consistent with the requisite regional oversight and campaign management and the necessary rapid response. It also ensures that political considerations figure strongly in the assistance provided; for example, Sahelian countries are consistently major recipients of emergency assistance during upsurges, regardless of whether large-scale operations prove to be necessary. Mechanisms have been proposed by FAO and others to better match supply and demand and to provide for a more rapid response where this is needed, but have not received the necessary support from donors. One would be to establish a regional or international contingency fund immediately that calls on substantial international assistance appeared likely; another would be to establish banks of pesticide and possibly other necessary equipment which could be accessed quickly and flexibly; this would also prevent unnecessary and hazardous stockpiles being left in recipient countries.

### **Disconnect between research and operations**

There is no agreed and affective coordinating mechanism for oversight of research needs in support of Desert Locust management. While FAO's Desert Locust Control Committee (DLCC) has held the mandate for research policy on locusts since 1955, outside this structure, in 1989, a Scientific Advisory Committee (SAC) was established by the Consultative Group on Locust Research (CGLR), co-sponsored by UNDP and FAO. This move separated research and locust control operations in the FAO committee structure. DLCC has expressed concern that funds have been preferentially provided for long-term research by developed country researchers at the expense of preventive applied research schemes proposed by affected countries, which include training and institution-building to secure adequate survey and control during lengthy recessions (FAO, 1993c.). In the meantime, most major donors prefer to go there own way through bilaterally funded programs or consortia of these.

A confused approach to research management is almost inevitable in the absence of a broadly agreed and realistic control strategy, without which it is difficult to see how research and development needs can be properly defined. At present, the research community is the most active group attempting to define strategies but it is without solid foundation in terms of identified short- and long-term needs and effective downstream institutions. There is a risk that a mismatch between supply and demand for research will occur. For example, there is considerable emphasis being placed on tools and techniques of preventive control but little or no emphasis on development of impact assessment methods and decision tools for national control strategies and improved preparedness, or appropriate institutional and information systems for rapid response.

#### **Lack of effective technical advice**

Establishment of a long-term strategy for Desert Locust management requires that the lead agency or agencies have the vision, resources and technical credibility to bring all relevant actors on board: its implementation also requires effective monitoring, evaluation and oversight in the face of changing needs and circumstances of the affected countries and institutions. This capacity is substantial and beyond that which the FAO Migratory Pest Group and the existing DLCC technical advisory structure can currently bring to bear. The Migratory Pest Group does not have the requisite multi-disciplinary resources and has little regular professional contact with FAO divisions or other groups concerned with long-term economic and institutional issues and policy development. The DLCC/Technical Working Group has not been a consistently available source of technical advice and the role earlier played by the Anti-Locust Research Centre, which undertook strategic and economic analysis until the 1980s, has not been filled.

#### **Aid dependency**

In the majority of Desert Locust-affected countries little, if any, progress is being made towards sustainable local control capacity and self-reliance. Lipton (1986) describes a common effect in countries with budgets dominated by foreign aid: the recipient government shifts attention from development management to aid management. This appears to have been the case in several Sahelian countries receiving assistance for locust and grasshopper control. The National Service de Protection Vegetaux (SPV) in Mali, created in 1987, has been from the onset dependent on donor assistance, including the provision of free pesticides: in the 12 months to October 1991, over 90% of recurrent costs were donor-financed (Kremer, 1992). Similar situations occurred in Burkina Faso, Niger and Senegal and other countries; 75% of the costs of Senegal's plant protection service were donor-financed during 1988-89; the figure is 96% for Niger in 1988. All of Sudan's pesticide use between 1986 and 1990 was subsidized (Farah, 1994).

In principle, it can be argued that these subsidies were warranted in the face of a short-term emergency. However, the provision of free donor-financed pesticides fueled an existing propensity of governments in the region to subsidize pesticide use and continued well after the threat of locust and other migratory pests receded. Thus, in 1991, at least two thirds of the pesticides used by around 3,000 village brigades in Niger were donated (Kremer, 1992). In Mali, the area treated by the SPV in 1990-91 was greater (460,334 ha) than at the height of the upsurges in 1987-88 (330,597 ha) (USAID, 1994). Kremer and Lock (1992) argue that the donation of free pesticides and associated training, research, equipment etc. was effectively adopted as a long-term strategy for chemical-based plant protection in the western Sahel by both governments and donors, following the end of the 1986-89 campaign.

Table 4. Countries affected by Desert Locusts<sup>a</sup>: agriculture indicators, production threatened and assistance received.

Countries	Agricultural Economy				Agr. Production at Risk					Desert Locust Invasion & Assistance			
	Recession Area	Agr. GDP 1992 (mil \$)	Agr. in total GDP (%)	Agr. pop. (%)	Agr. GDP per ha crop land <sup>b</sup> (\$ per ha)	Percent Irrigated (%)	Share of production <sup>c</sup>			Most imp. cereals <sup>d</sup>	Exports at risk <sup>e</sup>	cropping area subject to invasion <sup>f</sup> (%)	Prob. of swarms/bands in avg. year <sup>g</sup>
						Cereals (%)	Livestock (%)	Other (%)					
Algeria	5351	15	23	699	5	20	44	36	wheat, barley	fruit, veg.; bev	100	0.53	31.59
Chad	549	44	84	171	0	18	34	48	millet, sorghum	cotton; livestock	100	0.41	16.47
Djibouti	...	...	...	...	...	...	...	...	...	...	100	0.38	0.48
Egypt	6040	18	39	2285	100	26	27	47	wheat, maize	fruit, veg; cotton	100	0.41	1.36
Eritrea	...	...	...	...	...	...	...	...	...	...	...	...	0.97
Ethiopia	3003	48	71	216	1	26	39	35	maize, barley	bev, spice; livestock	90	0.83	9.67
India	68671	32	63	405	27	33	21	46	rice, millet	bev., spices; fruit, veg	20	0.7	0.35
Iran	25359	23	25	1685	38	23	31	46	wheat, barley	fruit, veg.; bev., spices	80	0.6	0.20
Libya	1092	4	15	506	11	6	49	45	barley, wheat	fruit, veg.; veg. oil	100	0.38	0.30
Mali	1187	42	91	565	10	27	42	31	millet, sorghum	cotton; livestock	100	0.49	28.73
Mauritania	313	29	67	1528	6	9	83	7	sorghum, rice	livestock	100	0.56	36.40
Morocco	4260	15	35	452	14	29	26	45	barley, wheat	fruit, veg.; bev., spice	100	0.55	37.29
Niger	868	37	89	241	1	43	33	24	millet, sorghum	livestock; fruit, veg.	100	0.55	23.00
Oman	1843	16	40	30216	95	0	...	...	wheat, sorghum	livestock; fruit, veg.	50	0.49	0.25
Pakistan	11314	27	56	535	80	19	40	42	wheat, rice	rice; cotton	90	0.8	1.22
Saudi Arabia	7794	7	34	3282	40	34	42	24	wheat, sorghum	wheat; fruit, veg.	100	0.76	...
Senegal	1193	19	74	508	8	15	28	57	millet, sorghum	veg. oils; oil crops	100	0.31	25.04
Somalia	571	65	76	550	11	3	88	10	sorghum, maize	livestock; fruit, veg.	100	0.66	1.59
Sudan	4645	30	56	360	15	16	54	30	sorghum, millet	cotton; livestock	60	0.79	33.89
Tunisia	2494	18	24	512	5	24	30	46	wheat, barley	veg. oils; sugar, honey	100	0.3	9.87
U.A.E	1274	3	2	32667	13	0	...	...	wheat, none	fruit, veg.; bev., spices	50	0.44	...
Yemen <sup>1</sup>	2019	21	0	1254	19	6	53	41	wheat, maize	fruit, veg.; bev.,spices	100	0.69	4.18

continued on the next page

Table 4. (continued) Countries affected by Desert Locusts<sup>a</sup>: agriculture indicators, production threatened and assistance received.

Countries	Agricultural Economy				Agr. Production at Risk					Desert Locust Invasion & Assistance			
	Agr. GDP 1992 (mil \$)	Agr. in total GDP (%)	Agr. pop. (%)	Agr. GDP per ha crop land <sup>b</sup> (\$ per ha)	Percent Irrigated (%)	Share of production <sup>c</sup>			Most imp. cereals <sup>d</sup>	Exports at risk <sup>e</sup>	cropping area subject to invasion <sup>f</sup> (%)	Prob. of swarms/bands in avg. year <sup>g</sup>	Locust/Grasshpr asst. received 1986-94 (mil. \$) <sup>h</sup>
						Cereals (%)	Livestock (%)	Other (%)					
Other													
Afghanistan	...	...	60	...	34	28	47	24	wheat, maize	fruit, veg; wool, cotton	30	0.3	...
Burkina Faso	1228	44	83	345	1	34	26	40	sorghum, millet	cotton ; livestock	...	...	12.58
Cape Verde	...	...	...	...	...	...	...	...	...	...	...	...	1.66
Gambia	68	30	82	377	7	17	23	60	millet, maize	oilseed, feed; veg. oil	100	0.89	4.75
Guinea	1067	33	56	1461	4	27	17	56	rice, maize	livestock; bev., spices	...	...	3.03
Guinea-Bissau	97	44	75	285	0	30	26	44	rice, millet	fruit, veg.; cotton	...	...	1.23
Iraq	...	...	22	...	47	12	36	52	wheat , barley	fruit, veg.; livestock	90	0.39	0.48
Jordan	286	7	6	712	16	3	38	59	barley, wheat	fruit, veg; dairy	100	0.41	1.24
Kenya	1859	27	76	762	2	11	49	40	maize, sorghum	bev., spices; fruit, veg	100	0.44	0.11
Kuwait	191	1	1	38298	40	...	...	...	none	dairy	100	0.41	...

Sources: World Agriculture, 1970-91; World Development Report, 1994; African Development Indicators; Gruys, P. (1990); FAO-DLCC Session Reports; FAO-ECLO Data;

Algeria, Desert Locust Control, Project Completion Report

Notes: "..." : data unavailable; data in *italics* are from prior years due to unavailability for 1992

<sup>a</sup>Countries included, are recession area and those receiving > = \$1 mil. aid or with > = .3 probability of invasion;

<sup>b</sup>Includes arable and permanent crop land

<sup>c</sup>measured in international \$; developed by FAO as 1971-81 average of prices in different countries after conversion into a common currency unit.

<sup>d</sup>top two by area (ha)

<sup>e</sup>top two groups at risk from Desert Locusts, by value; commodities assumed at risk: cereals, cotton, fruit, honey, livestock (rangeland), oil seeds, pulses, sugar, vegetables

<sup>f</sup>Estimated % of total area of arable and permanent crop land within maximum known Desert Locust invasion area; FAO-DLCC 26th Session.

<sup>g</sup>Calculated as: mean frequency, presence of swarms and bands 1939-78 divided by 40 yrs; FAO-DLCC 26th Session, Rome, 4-8 October 1982

<sup>h</sup>Locust and Grasshopper programs assistance calculated from: Gruys, P. 1990; FAO-DLCC Session Reports; FAO-ECLO data; and WB PCR. Figures include \$ estimates for "in kind assistance".

Algeria figure includes \$22 mil. disbursement of WB loan of \$ 58 mil. approved, other bilateral assistance only as reported to FAO and may not be complete. Includes '93/94 emergency to June '94

<sup>i</sup>includes Yemen, AR and Yemen, PDR



While an economic case can be put for subsidizing control of a major migratory pest outbreak such as those of Desert Locust (or *Senegalese grasshoppers* when aggregated swarms have formed), there is weak, if any, justification for ongoing subsidized use of pesticides as crop protection agents against the wider complex of pests affecting the rainfed millet and sorghum belt of the Sahel (Jago et al., 1993). This policy is financially unsustainable, as the SPV has no budget to purchase pesticides or mount spray campaigns and cannot recover costs from some of the poorest farmers in Africa. It is also economically unsound: in the subsistence millet and sorghum belt, returns to labor hire for first weeding or extensification of production are usually greater than those from purchase of pesticides.

In general, problems of subsidizing pesticide spray campaigns are that:

- Plant protection services come to be seen as a providers of free pesticides and come under pressure to divert pesticides into control of pests other than locusts;
- Pesticides are used inefficiently;
- The availability of attractive per diem payments and other institutional support equipment, (vehicles) provided scope for self interest in the reporting of pest outbreaks;
- Farmers become unwilling to participate in crop protection projects unless free pesticides are provided;
- The allocation of resources between plant protection services and long-term agricultural research establishments is distorted.

# RECOMMENDATIONS

## Strategic Framework

Multiple constraints currently impede effective Desert Locust management. Progress is dependent on improvement in policy, institutions and technology, at all levels, with the cooperation and commitment of both the affected countries and the international community. It requires a broadly agreed strategic framework within which individual country and donor programs, and those of regional and internationally mandated bodies, are fully consistent. Some important strategic shifts are shown in Table 5.

**Table 5. Strategic shifts required in Desert Locust management**

<b>From</b>	<b>To</b>
Emotive response	Needs-oriented response based on assessed risks
Emergency technical assistance	Long- and short-term policies and programs
High degree of external dependency	Sustainable institutions in affected countries
Large-scale chemical control	Tools and tactics based on IPM principles
Indiscriminate control strategy	Knowledge-based and targeted approach
Limited technical perspective	Inclusion of economic and environmental criteria

## National Programs and Regional Networks

Ultimately, effective management of Desert Locusts rests with the affected countries. Sound policies and programs at this level are the essential building blocks of an internationally effective management plan. There is no blueprint for a national Desert Locust strategy, or for the policy and program priorities that flow from it. However, it would be advisable to develop specific components in relation to:

- **Policies:** analyzing risks and placing the threat from Desert Locusts in the context of (i) crop protection priorities, and (ii) national disaster preparedness and mitigation policies. Risk assessment identifies the nature and scale of potential impacts in relation to agricultural systems and communities, including the timing of infestations in relation to major crops. Preparedness policies assess the legal and institutional requirements and contingency plans in order to act rapidly in the event that major impacts are likely; mitigation policies include both short- and long-term risk-stabilizing measures and safety nets, including crop insurance and/or relief efforts.

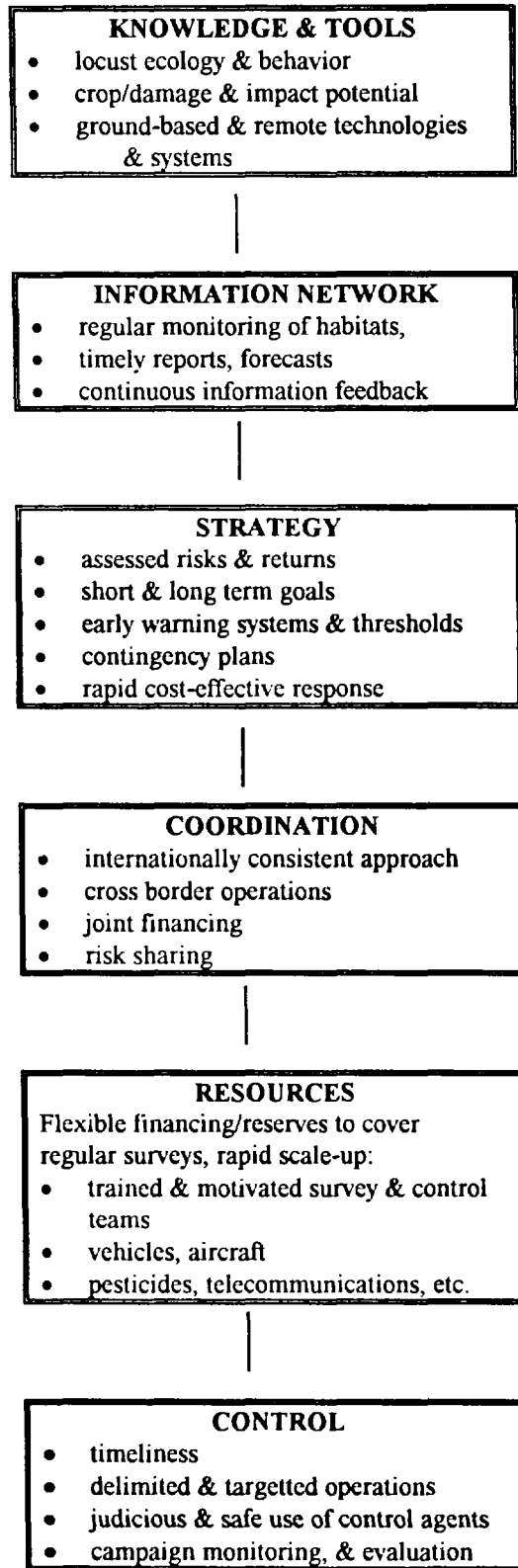
- **Locust management strategies:** setting out national objectives for locust control and detailing operational procedures and environmental mitigation measures. The latter should include country-specific environmental assessments, including inventories and maps of sensitive and protected ecosystems and hazard information for chemicals to be used. The need for and means of locust control at the national level need to be elaborated in the context of wider IPM strategies, including those coordinated regionally, targeting priority pests and cropping systems. Synergies between resources and institutions involved in management of locusts and other pests need to be identified, including roles during recession and plague and the maintenance of small permanent survey units as required.
- **Information and early warning systems:** the means to collect, interpret, send and receive essential information on locust habitats and populations, vegetation indices and meteorological data; the effective utilization of local knowledge and information from villagers and nomads, perhaps facilitated by NGOs. The installation of radio and other rapid communications equipment such as small PC-based satellite receivers, faxes and e-mail; the integration of information from locust forecasting and meteorological stations; agriculture and environment information networks and early warning systems; the overhaul of policies in relation to the free flow of information from rural areas;
- **Cross-border agreements and cost-sharing arrangements:** information exchange and risk-sharing mechanisms with neighboring countries where sites of known breeding and gregarization and/or seasonal migration routes indicate mutual interest in joint or coordinated activities, including any permanent locust monitoring, surveillance or control units.

## **Donors' Supporting Roles**

Donors can assist affected countries to strengthen their capacity to act against the Desert Locust through long-term country assistance programs. In doing so, there are some key considerations:

- As with support for crop protection measures generally, the aim should be to identify and support capacity for which the benefits outweigh the costs, in terms of avoiding clearly identified risk of economic or social impacts in agriculture, and for which recurrent costs will be met by the affected country.
- Donors have the option to require national control policy statements including environmental risks and mitigation measure as a condition of pesticide provision, and to assist and monitor compliance with the agreed policy by the provision of appropriate technical assistance and training. This step is justified on the basis that, in the past, use of pesticides in locust control has often been wasteful and environmentally damaging.
- There is considerable opportunity for synergies with other components of a long-term country assistance strategy. In particular the provision of support for environmental and other information systems, for famine early warning systems and disaster preparedness, and for policies and programs in support of risk-stabilizing measures including functioning rural markets and credit schemes.

**Fig. 5. Building blocks of locust management**



In several cases, neighboring countries and groups of countries have identified sufficiently strong common interests to collaborate and recurrently finance regional monitoring and control organizations. These are a very positive feature, the 'Force Maghreb' being a good example. However the coverage provided by these organizations is incomplete. Arguments are periodically put that donors should subsidise additional capacity at a regional level, ranging from international 'strike forces' to more permanent structures, in an attempt to guarantee permanent coverage of key breeding and gregarization sites. The case is put on the basis of the 'public good' argument that benefits accrue to all countries within the invasion area and to the international community in the form of cost savings to emergency control.

- Donor policy should be that the funds for such capacity are sought in the first instance from trust funds established by locust-affected countries. FAO DLCC and regional trust funds are existing examples. Incremental international assistance is justified for monitoring and surveillance initiatives, as the value of information for locust management is clear. International subsidy of regional control capacity, other than that which may be provided through country assistance programs, cannot be justified on economic grounds, nor is it consistent with long-term institutional sustainability. The argument that bearing the recurrent costs of regional capacity is cheaper than financing periodic emergency operations fails to address the fact that targeted international assistance, when necessary, could be provided considerably more cost-effectively than at present.

## **Regional Preventive Control**

There is some interest currently in the establishment of a regionally coordinated survey and early control capacity, initially in the central region of the Desert Locust outbreak area. This would be implemented as an FAO regional program, for which donor support is being sought (see Box 11). Such a program is positive in that it includes a long-required emphasis on the most important of the Desert Locust areas in terms of upsurge development, and is also consistent with the long-term goal of removing the threat of Desert Locust plagues. However, there is risk that the political desirability of the scheme which, if it were successful, would remove or at least substantially reduce the possibility of crop damage, will over-ride fundamental issues of technical feasibility, economic viability and institutional sustainability. Donor support for such a program is not justified in the long term. A clear path towards disengagement of international support should be identified, consistent with a progressive development of ownership and responsibility for the scheme by participating countries. The latter point indicates that the systems and tools employed will need to be robust and affordable in the context of national capacities and commitments to finance recurrent costs.

Such a program would need to be allied to and consistent with development of national control strategies, policies and systems, including support for these developments through bilateral programs. It will be essential to include means to monitor and evaluate operations and impacts. The program should be seen as an interim initiative with a finite life, rather than a permanent program.

## **Risk Assessment and International Control Policy**

The most important shift in overall control strategy will be to move away from controlling **all** gregarizing and gregarious populations, to a strategy that is based on the principles of integrated pest management (IPM), so that *the risks associated with the Desert Locust are assessed and mitigated by a variety of available means designed to keep economic, social and environmental impacts within acceptable threshold limits.*

In the early stages of an upsurge, the risks and necessary actions are localized. National strategies, including contingency plans and their implementation, and the activities of regional country groups and organizations, supported by a permanent international information and forecasting network, are the first order of defense. The timing and targeting of operations is a matter for national policy; risk analyses and environmental impact assessments will help to define appropriate actions and the basis of any requests for donor assistance.

#### **Box 11. FAO's proposed emergency prevention system (EMPRES)**

The objective of the FAO's proposed EMPRES scheme is to prevent locust upsurges and plagues through the implementation of an effective monitoring, survey, early warning and control program supported by research on relevant aspects of locust ecology and control.

Initially focus would be concentrated on FAO's Central Region (Egypt, Eritrea, Ethiopia, Oman, Saudi Arabia, Sudan, Yemen) as the primary source of upsurges and potential plagues. An FAO Field Program with a base in the Red Sea area would support monitoring and early control activities. Upsurge prevention would be implemented on a regular and long-term basis, through:

- Establishment of an improved, cooperative early warning system, based on integration of remote sensing technology with regular ground/aerial surveys.
- Strengthening of national and regional capacities for responding rapidly to the presence of Desert Locust infestations.
- Rapid access to aircraft, strategic stocks of equipment and pesticides, as well as contingency funds.
- Development and testing of contingency plans and strategies for improved responses to emergencies.
- Development and implementation of operational guidelines and procedures to minimize potentially adverse environmental impacts arising from chemical control.
- A structured and targeted program in Desert Locust control to enhance the capacity and capability of the staff of national agencies.
- Provide a platform for the extensive field testing of new monitoring and control techniques.
- Supporting and coordinating a cooperative research program aimed at better understanding and control of the Desert Locust.

Core funding for EMPRES would be provided through FAO's regular program. However, additional financial support through a multi-donor Trust Fund would be needed to develop and implement a comprehensive program and to maintain a contingency fund. Support and collaboration would also be solicited from affected countries and the services of national agencies and regional organizations would be used where possible and cost-effective. A donor support group would be established and based on a commitment to long-term support subject to accountability by the program. The required recurrent annual budget for activities in Near East is estimated at US\$4 million and initial capital set-up cost at US\$1.5 million. Support would be given to other regions as additional resources become available.

Activities would be closely linked with FAO's Migratory Pest Group, which would continue to serve as a headquarters for locust information exchange and forecasting on a global basis. The Migratory Pest Group at FAO in Rome would also develop further an international, collaborative research program, involving donors, affected countries and relevant research institutes.

On the assumption that further upsurges and plagues of the Desert Locust will occur, the international community needs to be able to deal with this eventuality on the basis of maximum preparedness. Progress is needed in the following areas:

- the requisite flexibility to resource campaigns that are regional in scope,
- operation of a consistent and cost-effective strategy,
- de-politicization of assistance, and
- control targeted on the basis of impacts.

Establishment of an internationally recognized alert system is an important step to support such progress. The functions of the system would be to define a series of intervention thresholds at which

agreed contingency plans would come into effect. Upsurges do not happen overnight; the first-alert stage would correspond to the existence of favorable breeding conditions in known key sites; subsequent stages would correspond to the progressive development of the locust population as a whole and to the emergence of clear and identifiable threats to agriculture and agricultural communities.

There are several actions that the international donor community should take at the first point at which the possibility exists of serious impacts which cannot be contained by the capacity and resources of the countries affected. These are already known and include activation of FAO/ECLC, establishment of non-tied regional contingency funds, and establishment of pesticide and equipment banks.

Once a major upsurge has developed, it is doubtful whether the continuation of a policy of supporting control campaigns through bilateral emergency grants and loans provides an effective means to match the supply and demand for resources -- it leads to duplication, is open to abuse, and is technically inefficient in the face of a regionally mobile pest. A more effective strategy, once an agreed threshold level is reached, would be to employ regionally coordinated campaigns mounted under the direct supervision of a single lead agency, drawing on national control teams. Campaigns would be resourced from pre-established contingency funds and pesticide/equipment banks, with all disbursements approved by an objective technical advisory body with undisputed international credibility.

The basis of the control policy for internationally coordinated campaigns needs to be unambiguously established. The strategic framework recommended by this study indicates strongly that control operations should only be effected where there is (i) an assessed and defined risk to high-value agricultural systems or vulnerable subsistence agricultural communities and/or (ii) genuine opportunity for maximum, cost-effective impact on the Desert Locust population as a whole.

Implementation of this strategy will require:

**Full information.** It is absolutely essential that decision-makers at national, regional and international level have the information needed in order to be able to **act quickly and appropriately**. The means to receive and interpret locally relevant information, based on ground habitat monitoring and remote-sensing, and to effect rapid transfer of this information nationally and internationally, is a key priority area for support through long-term bilateral or multilateral assistance. However such support should carry with it guarantees concerning regular reporting, as advised by FAO during both recessions and upsurges.

**Development of decision tools.** The further development of simulation models of the kind used at the 1994 Wageningen workshop (Van Huis 1994), underpinned with considerably better attention to monitoring and evaluation of control measures, will lay the basis for tactics to be assessed on cost-effectiveness grounds. At the same time, the proposed FAO RAMSES and other programs to develop improved monitoring and forecasting technology need to expand their objectives to incorporate parameters and relevant indicators related to economic and social impact. Predictive impact assessments are currently starved of suitable indicators and field data. Impact assessments following locust infestations of crops should become a standard feature of donor-supported programs.

The development of an improved database on the agricultural systems and communities at risk from Desert Locusts is essential; this process can draw on the environmental information systems being supported by the World Bank and other donors using common information sources, including satellite NDVI and rainfall data. Joint work programs between famine early warning systems and locust forecasting groups are an option which could be explored to obtain land-use data, crop forecasts and vulnerability indices.

Impact assessment needs applied research to develop cost-effective, standardized methods which are adapted to cropping systems, institutions and available resources. Reliance on comprehensive crop loss assessments is unrealistic in remote semi-arid areas; rapid appraisal methods and indirect impact indicators are needed.

**Improved control and application.** A suite of improved, environmentally more benign control technologies are likely to become available in the medium term, including insect growth regulators and pathogens; the proposed FAO field program in the Red Sea region provides a useful opportunity to accelerate this process. In the meantime ULV spraying of conventional pesticides should be used for Desert Locust control unless the benefits of choosing other methods outweigh the loss of cost-efficiency and speed. In this case it is essential that equipment supplied and used for ULV application against Desert Locust should be not only effective but efficient in use of pesticides and time, safe for operators and the environment, and reliable. Regional control campaigns need to be able to draw on experienced and motivated personnel from national control teams. Regular training requirements need to be assessed and appropriate courses devised for ground spraying teams (pesticide safety and ULV application techniques, routine maintenance) and their supervisors (supervisory and inspection skills), spray pilots and engineers (application). Training for senior locust campaign staff would include the logistics of campaign management.

Technical appraisal and field validation of rotary-atomizer ULV sprayers for aerial and ground-based application must be carried out to assess and, if necessary, improve reliability of potential sprayers for provision as part of donor assistance to Desert Locust control programs.

Experienced personnel should be assigned to the monitoring and reporting of operations. Control staff and pilots should also be required to complete detailed control records during the operations. New technology being introduced to aircraft (GPS spray systems) can provide a greater level of transparency and accountability to aerial operations. Trials of this equipment are required to assess its value for Desert Locust control.

## **Consensus and Change**

The strategic shifts outlined above will not be easily achieved, either technically, or in social and political terms, but their time has come. The international community cannot continue to engage in large-scale, indiscriminate and expensive control measures to prevent or contain plagues. The basic policy pursued by FAO, UNDP and other donors since the 1970s, to emphasize the role of crop protection and related resources of affected countries, remains essentially correct. The establishment and maintenance of regional structures and networks will be considerably more sustainable where this comes about through the initiatives of affected countries. Up to this point, however, the policy has been poorly pursued, based on a disparate assembly of initiatives, bilateral and multilateral, which failed to adequately support and maintain essential capacity, and left the way open to a succession of 'emergencies.' A managed process of change is needed, over the next 10 years, in which the policies and systems to monitor locusts and their habitats and to take effective early action, including the financing arrangements, are built and maintained by the affected countries with international support for this process. The proposed FAO EMPRES scheme will be a useful step in this direction, provided it is designed and implemented with the objective to establish robust and affordable capacity and then progressively to disengage. This requirement goes beyond simply testing new technology and includes assistance to develop effective policies and institutions. As the financial responsibility for Desert Locust management shifts to the affected countries, either individually or collectively through trust fund arrangements, the need for a targeted, impact-oriented response to the risks created by locusts will shape the strategies adopted. They will need to be cost-effective. A balance will need to be found between the political pressures, which are an inevitable characteristic of locust management, and the realistic capacity of Desert Locusts to cause economic and social hardship.

The vision and leadership required to bring about the necessary consensus to support such changes places a heavy responsibility on the FAO committee structure and operational bodies. The current lack of consensus and inconsistency of approach between bilateral donors and FAO is a major constraint on progress which needs to be resolved urgently.



## REFERENCES

- Anderson, J.R. & Dillon, J.L. (1992) 'Risk Analysis in Dryland Farming Systems'. Food and Agriculture Organization. Farm Systems Management Series no. 2. FAO, Rome.
- Balanca, G. & de Visscher, M., 1994. *Les Degats des Criquets Pelegrins en Mauritanie et au Senegal*. CIRAD-GERDAT-PRIFAS, Montpellier, France.
- Bateman, P. 1993. *Mycopesticides as potential agents for desert locust control*. Abstract. In: Report of FAO International workshop on research and planning for desert locust control held in Marrakech, Morocco, 24-28 May 1993. FAO, Rome.
- Belayneh, Y.T. 1993. *Amendment to the USAID/Madagascar supplementary environmental assessment of the locust control program: options for including insect growth regulators (IGRs), for locust/grasshopper control*. August 1993. USAID, Antananarivo, Madagascar.
- Bennett, L.V., 1976. 'The development and termination of the 1968 plague of the desert locust'. *Bulletin of Entomological Research*, 66, 511-552.
- Brader, L., (1989) Director of the FAO's Plant Production and Protection Services Division. Written review of an OTA draft report.
- Bullen, F.T., 1972. "A review of the assessment of crop losses caused by locusts and grasshoppers". pp. 163-171. In: *Proceedings of the International Study Conference on the Current and Future Problems of Acridology*, London, United Kingdom, 6-16 July 1970. eds C.F. Hemming and T.H.C. Taylor. London, Centre for Overseas Pest Research.
- Castleton, C.W., 1991. *Provisional report on the use of village brigades in Sahelian grasshopper and locust control programmes, with emphasis on Mauritania, Senegal, Cape Verde, Mali, Chad and Northern Cameroon prepared on behalf of the FAO*.
- Commission of the European Communities 1992. Final Report of a Conference 'Atelier sur le Methodologies de Recherche en Ecologie des Traitments Anti-Acridiens en Afrique', held at CIRAD, Montpellier, France between 24 - 18 February 1992.
- Coop, L.B., Croft, B.A., Murphy, C.F., and Stanley F. Miller, 1991. "Decision support system for economic analysis of grasshopper treatment operations in African Sahel". *Crop Protection*, 10: 485-495.
- Coop, L.B. and Croft, B.A., 1993. Pearl millet injury by five grasshopper species (*Orthoptera: Acrididae*) in Mali. *Journal of Economic Entomology*, 86 (3): 891-898.
- Courshee, R.J. 1990. "Desert Locusts and their control". *International Pest Control* 32: 16-18.
- Cressman, K. Locust Survey and Forecasting Officer, Locust, Other Migratory Pests & Emergency Operations Group, Plant Production and Protection Division, FAO, Rome.
- Dynamac International. 1988. *Results of the Mali pesticide testing trials against the Senegalese Grasshopper*. Draft Technical Report for USAID. Dynamac International, Inc, Rockville, MD.
- Everts, J.W. 1990. *Environmental effects of chemical locust and grasshopper control*. A pilot study. FAO, Rome, Italy.

- FAO. 1968. *Desert Locust Project. Final report.* Rome, FAO report no. FAO./SF:34/DLC. Rome, Italy
- FAO. 1982. *Report of the Twenty-Sixth Session of the FAO Desert Locust Control Committee, held in Rome, Italy, 4-8 October 1982.*
- FAO. 1985. *Report of a Consultation on Desert Locust Plague Prevention in the Central Region, Rome, 28-30 May 1985.* Rome.
- FAO. 1990. *Report of the Thirty-first Session of the FAO Desert Locust Control Committee, Rome, Italy, 24-28 September 1990,* Rome, Food and Agriculture Organization, Plant Production and Protection Division.
- FAO. 1992. *Report of the Thirty-second Session of the FAO Desert Locust Control Committee, Rome, Italy, 12-16 October 1992.* Rome, Food and Agriculture Organization, Plant Production and Protection Division.
- FAO. 1993. *Reconnaissance And Management System of the Environment of Schistocerca Desert Locust RAMSES. Programme Outline for Future Requirements in Remote Sensing and Modeling and their Integration using GIS to Improve Desert Locust Forecasting.* Food and Agriculture Organization. Rome.
- FAO. 1993a. *Production Year Book 1993.* Rome.
- FAO. 1993b. *Food Outlook. Global Information and Early Warning System GIEWS on Food and Agriculture.* no 12, 1993. FAO Rome.
- FAO 1993c. *Report of the Thirty-second Session of the FAO Desert Locust Control Committee, Rome, Italy, 12-16 October 1992.* Food and Agriculture Organization, Plant Production and Protection Division.
- FAO. 1994a. *Food Crops and Shortages. Global Information and Early Warning System GIEWS on Food and Agriculture. Special Report, no 2,* FAO, Rome.
- FAO. 1994b. *Report on a Meeting of Donor Countries, Donor Institutions and Affected Countries on the Desert Locust Emergency 1993-94.* FAO. Rome 29 April 1994.
- FAO. 1994c. *The Desert Locust Guidelines: Volume Five, Campaign Organization and Execution.* Rome.
- FAO. 1994d. *The Desert Locust Guidelines: Volume Four, Control.* Rome, FAO.
- FAO. 1994e. *The Desert Locust Guidelines: Volume One, Biology and Behavior.* Rome, FAO.
- FAO. 1994f. *The Desert Locust Guidelines: Volume Three, Information and Forecasting.* Rome, FAO.
- FAO. 1994g. *The Desert Locust Guidelines: Volume Two, Survey.* Rome, FAO.
- Farah, J 1994. *Pesticide Policies in Developing Countries.* World Bank Discussion paper no 238.
- Faure, J.C., 1923. The life-history of the Brown Locust, *Locusta pardalina* Walker. *Journal of the Department of Agriculture Union of South Africa*, 7:205-24.
- FEWS, 1987. (Famine Early Warning System) *1986 Grasshopper and Locust Infestations.* Africa Bureau, A.I.D. Washington, D.C.
- FEWS, 1992. *Vulnerability Assessment.* Famine Early Warning System, Arlington, VA.

- Fiskvatn, K. 1993. *Reduced dosages of the synthetic pyrethroid, Lambdacyhalothrin, and their effect on grasshoppers Acridoidea and non-target arthropods in Mali*. MSc thesis, Ecology. University of Oslo. 45 pp.
- Greathead, D.J. 1966. "A brief study of the effects of biotic factors on populations of the desert locust". *Journal of Applied Ecology*, 3: 239-250.
- Greathead, D.J. 1992. "Natural enemies of tropical locusts and grasshoppers: their impact and potential as biological control agents". In: Lomer, C.J. and Prior, C. Eds. *Biological control of locusts and grasshoppers*. CAB International, Wallingford.
- Gruys, P. 1992. *Grasshopper and locust campaigns 1986-1989 and FAOs role. A review*. Unpublished draft report to FAO, Rome, Italy. 184 pp
- Gruys, P., 1994 in press. "Lessons learnt from the last Desert Locust plague, 1985-89". Chapter 3. In: *Desert Locust Control using Existing Techniques: an Evaluation of Strategies. Proceedings of the Seminar held in Wageningen, The Netherlands, 6-11 December 1993*. Ed. A van Huis. Wageningen, Wageningen Agricultural University.
- Gudger, M. 1991. "Crop Insurance: Failure of the Public Sector and the Rise of the Private Sector Alternative". In Holden, D.; Hazell, P. and Pritchard, A. Eds. *Risk in Agriculture - Proceedings of the Tenth Agricultural Sector Symposium*. The World Bank, Washington, D.C.
- Hanley, M. 1989. Ancient enemy, new threat *World Development* Vol. 2 No. 1 (UNDP) p5-9.
- Hazell, P., et al Eds. 1986. *Crop Insurance for Agricultural Development*. International Food Policy Research Institute. Baltimore: John Hopkins University Press.
- IBRD. 1991a. *Environmental Assessment Sourcebook. Vol. I. Policies, procedures and cross-sectoral issues*. World Bank Environment Department. Technical Paper 139. 282 pp.
- IBRD. 1991b. *Environmental Assessment Sourcebook. Vol. II. Sectoral Guidelines*. World Bank Environment Department. Technical Paper 140. 282 pp.
- IBRD. 1993. *Algeria, Desert Locust Control Project, Project Completion Report*. Internal Document.
- IBRD. 1994a. *Final Draft Report on the Cotton Production Prospects Study-Appendices (Indian Case Study), Volume II*. New Delhi, A.F. Ferguson & Co.
- IBRD. 1994b. *World Development Report, Infrastructure for Development*. Oxford university Press. New York.
- IBRD/UNDP. 1992. *African Development Indicators*, Washington, D.C.
- IUCN, 1992. *Protected areas of the world: a review of national systems*. Vol. 2 Palaearctic; Vol. 3 Afrotropical. IUCN, Gland, Switzerland.
- Jago, N.D., Kremer, A.R. and West, C., 1993. *Pesticides on Millet in Mali*. NRI Bulletin, 50:45 pp. English version.
- Jago, N. D.ed. 1993. *Millet Crop-Loss Assessment Methods*. NRI Bulletin, 62: 61 pp. English version.
- Jepson, P. 1993. "The future of chemical control of locusts". Abstract. In: *Report of FAO International workshop on research and planning for desert locust control*. FAO, Rome.

- Joffe, S. 1993. *Socio-economic Aspects of the Biological Control of Locusts and Grasshoppers*. Report prepared for the International Institute of Biological Control. Draft NRI Bulletin, Chatham, Kent.
- Johannessen, B. 1991. *Reduced dosages of fenitrothion applied against grasshoppers Acrididae and short-term effects on non-target arthropods in Mali*. MSc thesis, Ecology. University of Oslo. 54 pp.
- Krall, S., & Nasseh, O.M. 1992. pp 44-49. In: Lomer, C.J. and Prior, C. Eds. *Biological control of locusts and grasshoppers*. CAB International, Wallingford.
- Krall, S., 1994. "Desert Locusts in Africa - A Disaster?". Paper. XXII International Conference of Agricultural Economists, 22-29 Aug. 1994. Harare, Zimbabwe.
- Kremer, A. R. 1992. "Pests and Donors in Mali, 1985-90". *Disasters*, vol. 16, no 3.
- Kremer, A. R., Lock, C. 1992. "A Decision Model for Sponsors of Crop Protection in the western Sahel". *Tropical Science*, vol. 32, no 4, pp. 397-419.
- Lambert, M.R.K. 1993. *Mission to Somali land to assess the effects of pesticide spillage on the Hargeisa environment 4 March to 3 May 1993*. Report of the ecotoxicologist. FAO, Rome. 44 pp.
- Lipton, M. 1986. "Aid-effectiveness, prisoners dilemmas and country allocation." *IDS Bulletin 17*, pp. 1-6. Institute of Development Studies, Brighton, Sussex UK.
- MacCuaig, R.D. 1970. "Locust control - the economic impact of new technologies". pp. 119-128. In: *The Technological Economics of Crop Protection and Pest Control*. Society of Chemical Industry Monograph No. 36.
- Magor, J.I., 1962. *Rainfall as a factor in the geographical distribution of the desert locust breeding areas, with particular reference to the summer breeding area in India and Pakistan*. PhD thesis, Edinburgh.
- Magor, J.I. Applied Ecology Division, Natural Resources Institute, Chatham, U.K.
- McCulloch, L. Consultant to ECLO, Plant Production and Protection Division, FAO, Rome.
- Mouhim, A., 1992. "CNLA; short report on the control strategy of acridids in Morocco 1987-89". In Lomer, C.J. & Prior, C. *Biological Control of Locusts and Grasshoppers*. CAB International, Wallingford.
- OTA. 1990. *A Plague of Locusts, Special Report*. U.S. Congress, Office of Technology Assessment, OTA-F-450. Washington, DC, Government Printing Office.
- Otteson, P., Fossland, S., Johannessen, B. and Simonsen, J.H. 1989. *Reduced rates of fenitrothion: the effect on Oedaleus senegalensis Orthoptera and non-target arthropods in Mali, West Africa*. Report to Royal Norwegian Ministry of Foreign Affairs. University of Oslo, Norway. 26 pp.
- Otteson, P.S. and Somme, L. 1990. *The impact of three pesticides, fenitrothion, lambda-cyhalothrin and teflubenzuron, on grasshoppers and non-target organisms in Mali, West Africa*. Report to Royal Norwegian Ministry of Foreign Affairs. University of Oslo, Norway. 40 pp.
- Pinto, L. J., Mann, J.B. and Bottrell, D.G. 1988. *Analysis of aerial application of fenitrothion ULV for locust control in Sudan*. Sudan Multi-donor Locust/ Grasshopper Control Programme. Consortium for International Crop Protection, College Park, MD. 90 pp.

- Pedgley, D.E., ed., 1981. *Desert Locust Forecasting Manual. Volume 1.* London, HMSO.
- Popov, G. B. 1965. *Review of the work of the desert locust ecological survey June 1958-March 1964 and the considerations and conclusions arising from it.* FAO, Rome. Report no UNSF/DL/ES/8.
- Potter, C. & Showler, A. 1991. "The Desert Locust: Agricultural and Environmental Impacts". In Zartman, I.W., Ed. *Tunisia - The Political Economy of Reform*". Lynne Rienner Publishers, Boulder & London.
- Prasada Rao, D. S. 1993. *Intercountry comparisons of agricultural output and productivity.* FAO Economic and Social Development Paper No. 112. Rome.
- Raina, S.K., 1992. "ICIPE; development of a biocontrol strategy for the management of the desert locust, *Schistocerca gregaria*". In: Lomer, C.J. & Prior, C. Eds. *Biological control of locusts and grasshoppers.* CAB International, Wallingford.
- Rowley, J. 1993. *Grasshoppers and Locusts - The Plague of the Sahel.* The Panos Institute, London.
- Showler, A.T. 1993. "Desert Locust, *Schistocerca gregaria* Forskal Orthoptera: Acrididae, campaign in Tunisia, 1988". *Agricultural Systems* 42 1993: 311-325.
- Showler, A.T. 1994. "Infestations de criquets en Afrique du Nord: protection de l'environnement et de sécurité humaine". In: *Deterioration de l'environnement de l'Afrique du Nord* A. Bencharifa and W.D. Swearingen, eds. Université Mohammed V Press, Rabat, Morocco.
- Smit, J.J. 1992, "CILSS/DFPV; the Permanent Interstate Committee for Drought Control in the Sahel, and the Department of Crop Protection Training, Niger". In Lomer, C.J. & Prior, C. Eds. *Biological control of locusts and grasshoppers.* CAB International, Wallingford.
- Steedman, A. Ed. 1988. *Locust Handbook.* 3rd edn. Chatham: Natural Resources Institute.
- Symmons, P.M. 1992. "Strategies to combat the desert locust". *Crop Protection*, 11, 206-12.
- Symmons, P.M. 1993. *The desert locust guidelines: IV. Control.* Food and Agriculture Organization of the UN, Rome.
- TAMS Consultants. 1989. *Locust and grasshopper control in Africa/Asia. A programmatic environmental assessment.* Report for USAID. Main Report + Executive Summary and Recommendations, 2 vols. TAMS Consultants, Inc., New York, NY and Arlington, VA.
- USAID. 1991. *Review of environmental concerns in A.I.D. programs for locust and grasshopper control.* USAID, Washington, DC. 71 pp.
- USAID 1992. Supplementary environmental assessment of the Madagascar locust control program. July, 1992. USAID and Government of Madagascar, Antananarivo, Madagascar.
- USAID.1993. *Food Sector Instability and Food Aid in Sub-Saharan Africa: Implications for food security.* Bureau for Africa. Office of Analysis, Research, and Technical Support, Technical Paper no. 10.
- USAID. 1994. *Pesticides and the Agrichemical Industry in Sub-Saharan Africa.* Report under contract by the Environment and Natural Resources Policy and Training EPAT Project of the Winrock International Environmental Alliance.
- USDA. 1994. *World Agriculture, Trends and Indicators, 1970-91.* US Department of Agriculture. Statistical Bulletin No. 861.

- Uvarov, B.P. & Bowman, B.M. 1938. "The economic importance of the locust and grasshopper problem throughout the world". pp. 190-236. In: *Comptes Rendus de la Vme Conférence Internationale pour les Recherches Antiacridiennes, Bruxelles, 1938*. Royaume de Belgique, Ministère des Colonies.
- Uvarov, B.P. 1921. "A revision of the genus *Locusta*, L. = *Pachytylus* Fieb. with a new theory as to the periodicity and migrations of locusts". *Bulletin of Entomological Research*, 12: 135-163.
- Uvarov, B.P. 1951. "Locust research and control 1929-1950". *Colonial Research Publication No. 10*. iv+67pp.
- Uvarov, B.P. 1977. Grasshoppers and Locusts. Vol 2. COPR, London. ix + 613 pp.
- Van Der Valk, H. 1993. Current knowledge on the environmental impact of locust control: a case study comparing fenitrothion and diflubenzuron. Abstract. In: Report of FAO International workshop on research and planning for desert locust control held in Marrakech, Morocco, 24-28 May 1993. FAO, Rome.
- van Huis, A. 1994a in press. "Can we combat the desert locust successfully?" Chapter 2. In: *Desert locust control using existing techniques: an evaluation of strategies, Proceedings of the Seminar held in Wageningen, The Netherlands, 6-11 December 1993*, Wageningen Agricultural University, Wageningen, The Netherlands.
- van Huis, A. Ed, 1994b in press. "Desert locust control using existing techniques: an evaluation of strategies". *Proceedings of the Seminar held in Wageningen, The Netherlands, 6-11 December 1993*, Wageningen Agricultural University, Wageningen, The Netherlands.
- Webb, P., von Braun, J., and Yohannes, Y. 1992. *Famine in Ethiopia: policy implications of coping failure at national and household levels*. International Food Policy Research Institute. IFPRI Research Report no 92.
- Wilps, H. 1994. Draft. *Report on the control of Schistocerca gregaria in Mauretania (August 1993 to February 1994)*. GTZ project: "Integrated biological locust control" PN 89.2031.6-01.100.
- Wright, D. 1986. Damage and loss in yield of wheat crops caused by the Australian plague locust, *Chortoicetes terminifera* Walker. *Aust. J. Exp. Agric.*, 26, 613-18.
- Wright, D.E. 1986b. "Economic assessment of actual and potential damage to crops caused by the 1984 locust plague in south-eastern Australia". *Journal of Environmental Management*, 23, 293-308.
- Wright, D.E., 1989. *Crop loss assessment feasibility study. Report on mission to Morocco and Mali 10 May to 8 June 1989 and draft project*. FAO Unpublished Report, Project ECLO/RAF/023/AFB.
- Zelazny, B. Technical Secretary, Locust Scientific Advisory Committee, Plant Protection Service, Agriculture Department, FAO, Rome.

## APPENDIX: ULV pesticides for Desert Locust control

This Appendix contains volume application rates and area dosage for ULV pesticide formulations in common use for Desert Locust control.

<i>Chemical name:</i>	<u>bendiocarb</u>	<i>Type:</i>	carbamate
<i>Recommended dose:</i>	100 g a.i./ha		
<i>Manufacturer:</i>	CAMCO		
<i>Brand name:</i>	Ficam		
<i>ULV formulation:</i>	ULV 20% (200 g/l)	<i>Rate:</i>	0.5 l/ha
<i>Chemical name:</i>	<u>chlorpyrifos</u>	<i>Type:</i>	organophosphate
<i>Recommended dose:</i>	225-240 g a.i./ha		
<i>Manufacturer:</i>	Dow Chemicals		
<i>Brand name:</i>	Dursban, Lorsban		
<i>ULV formulation:</i>	240 ULV (240 g/l)	<i>Rate:</i>	1.0 l/ha
	450 ULV (450 g/l)		0.5 l/ha
<i>Chemical name:</i>	<u>deltamethrin</u>	<i>Type:</i>	synthetic pyrethroid
<i>Recommended dose:</i>	15.0 g a.i./ha		
<i>Manufacturer:</i>	Roussel UCLAF		
<i>Brand name:</i>	Decis		
<i>ULV formulation:</i>	ULV 12.5 (12.5 g/l)	<i>Rate:</i>	1.2 l/ha
	ULV 25 (25 g/l)		0.6 l/ha
<i>Chemical name:</i>	<u>diazinon</u>	<i>Type:</i>	organophosphate
<i>Recommended dose:</i>	450-500 g a.i./ha <sup>a</sup>		
<i>Manufacturer:</i>	Ciba Geigy		
<i>Brand name:</i>	Basudin, Diazinon		
<i>ULV formulation:</i>	90 SCO (980 g/l)	<i>Rate:</i>	0.5 l/ha (swarms only)
<i>Manufacturer:</i>	Nippon Kayaku		
<i>Brand name:</i>	Dianon, Diazinon		
<i>ULV formulation:</i>	90% (w/vol.) 900 g/l	<i>Rate:</i>	0.5 l/ha (swarms only)
<i>Chemical name:</i>	<u>fenitrothion</u>	<i>Type:</i>	organophosphate
<i>Recommended dose:</i>	400-500 g a.i./ha		
<i>Manufacturer:</i>	Sumitomo		
<i>Brand name:</i>	Sumithion		
<i>ULV formulation:</i>	L-50 (500 g/l)	<i>Rate:</i>	1.0 l/ha
	L-100 (1000 g/l)		0.5 l/ha
	96% (w/w) technical		0.4 l/ha
	L-20 (200 g/l)		2.5 l/ha
<i>Chemical name:</i>	<u>fenitrothion + esfenvalerate</u>	<i>Type:</i>	organophosphate + synthetic pyrethroid
<i>Recommended dose:</i>	245 + 5 g a.i./ha		
<i>Manufacturer:</i>	Sumitomo		
<i>Brand name:</i>	Sumicombi-oc		
<i>ULV formulation:</i>	L-25 (250 g/l)	<i>Rate:</i>	1.0 l/ha
	L-50 (500 g/l)		0.5 l/ha
<i>Chemical name:</i>	<u>lambdacyhalothrin</u>	<i>Type:</i>	synthetic pyrethroid
<i>Recommended dose:</i>	20 g a.i./ha		
<i>Manufacturer:</i>	ICI		
<i>Brand name:</i>	Karate		
<i>ULV formulation:</i>	0.8 ULV (8 g/l)	<i>Rate:</i>	2.5 l/ha
	4.0 ULV (40 g/l)		0.5 l/ha (hoppers)

<sup>a</sup> Rate may sometimes be too low for reliable effective control (FAO Pesticide Referee Group, 1992).

<b>Chemical name:</b>	<u>malathion</u>	<b>Type:</b>	organophosphate
<b>Recommended dose:</b>	900 g a.i./ha		
<b>Manufacturer:</b>	American Cyanamid		
<b>Brand name:</b>	Malathion		
<b>ULV formulation:</b>	96% (w/w vol.) (960 g/l)	<b>Rate:</b>	0.9 - 1.0 l/ha
<b>Manufacturer:</b>	Cheminova		
<b>Brand name:</b>	Fyfanon		
<b>ULV formulation:</b>	96% (w/w) (1180 g/l) ULV technical	<b>Rate:</b>	0.75 l/ha
<b>Manufacturer:</b>	Cheminova		
<b>Brand name:</b>	Fyfanon		
<b>ULV formulation:</b>	ULV/EC (925 g/l) ULV/EC (1000 g/l)	<b>Rate:</b>	1.01 l/ha 0.9 l/ha
<b>Chemical name:</b>	<u>phoxim + propoxur</u>	<b>Type:</b>	organophosphate + carbamate
<b>Recommended dose:</b>	258 + 42 g a.i./ha		
<b>Manufacturer:</b>	Bayer		
<b>Brand name:</b>	Volaton-Unden		
<b>ULV formulation:</b>	UL 300 (300 g/l) UL 900 (900 g/l)	<b>Rate:</b>	1.0 l/ha 0.3 l/ha

Source: Symmons, P.H. 1993. The desert locust guidelines. IV. Control.  
Appendix 1. FAO, Rome, Italy. 64 pp.



# Distributors of World Bank Publications

## ARGENTINA

Carlos Hirsch, SRL  
Galeria Guemes  
Florida 165, 4th Floor-Ofc. 453/465  
1333 Buenos Aires

Oficina del Libro Internacional  
Alberti 40  
1082 Buenos Aires

AUSTRALIA, PAPUA NEW GUINEA,  
FIJI, SOLOMON ISLANDS,  
VANUATU, AND WESTERN SAMOA  
D.A. Information Services  
648 Whitehorse Road  
Mitcham 3132  
Victoria

AUSTRIA  
Gerold and Co.  
Graben 31  
A-1011 Wien

BANGLADESH  
Micro Industries Development  
Assistance Society (MIDAS)  
House 5, Road 16  
Dhanmondi R/Area  
Dhaka 1209

BELGIUM  
Jean De Lannoy  
Av. du Roi 202  
1060 Brussels

BRAZIL  
Publicacoes Tecnicas Internacionais Ltda.  
Rua Peixoto Gomide, 209  
01409 Sao Paulo, SP

CANADA  
Le Diffuseur  
151A Boul. de Montagne  
Boucherville, Québec  
J4B 5E6

Renouf Publishing Co.  
1294 Algoma Road  
Ottawa, Ontario  
K1B 3W8

CHINA  
China Financial & Economic  
Publishing House  
8, Da Fo Si Dong Jie  
Beijing

COLOMBIA  
Infoenlace Ltda.  
Apartado Aereo 34270  
Bogota D.E.

COTE D'IVOIRE  
Centre d'Édition et de Diffusion  
Africaines (CEDA)  
04 B.P. 541  
Abidjan 04 Plateau

CYPRUS  
Center of Applied Research  
Cyprus College  
6, Diogenes Street, Engomi  
P.O. Box 2006  
Nicosia

DENMARK  
Samfundslitteratur  
Rosenoerns Allé 11  
DK-1970 Frederiksberg C

DOMINICAN REPUBLIC  
Editora Taller, C. por A.  
Restauración e Isabel la Católica 309  
Apartado de Correos 2190 Z-1  
Santo Domingo

## EGYPT, ARAB REPUBLIC OF

Al Ahram  
Al Galaa Street  
Cairo

The Middle East Observer  
41, Sherif Street  
Cairo

FINLAND  
Akateeminen Kirjakauppa  
P.O. Box 128  
SF-00101 Helsinki 10

FRANCE  
World Bank Publications  
66, avenue d'Iéna  
75116 Paris

GERMANY  
UNO-Verlag  
Poppelsdorfer Allee 55  
53115 Bonn

GREECE  
Papasotiriou S.A.  
35, Stourmaria Str.  
106 82 Athens

HONG KONG, MACAO  
Asia 2000 Ltd.  
46-48 Wyndham Street  
Winning Centre  
7th Floor  
Central Hong Kong

HUNGARY  
Foundation for Market Economy  
Dombovari Ut 17-19  
H-1117 Budapest

INDIA  
Allied Publishers Private Ltd.  
751 Mount Road  
Madras - 600 002

INDONESIA  
Pt. Indira Limited  
Jalan Borobudur 20  
P.O. Box 181  
Jakarta 10320

IRAN  
Kowkab Publishers  
P.O. Box 19575-511  
Tehran

IRELAND  
Government Supplies Agency  
4-5 Harcourt Road  
Dublin 2

ISRAEL  
Yozmot Literature Ltd.  
P.O. Box 56055  
Tel Aviv 61560

ITALY  
Licosa Commissionaria Sansoni SPA  
Via Duca Di Calabria, 1/1  
Casella Postale 552  
50125 Firenze

JAMAICA  
Ian Randle Publishers Ltd.  
206 Old Hope Road  
Kingston 6

JAPAN  
Eastern Book Service  
Hongo 3-Chome, Bunkyo-ku 113  
Tokyo

## KENYA

Africa Book Service (E.A.) Ltd.  
Quaran House, Mfangano Street  
P.O. Box 45245  
Nairobi

KOREA, REPUBLIC OF  
Pan Korea Book Corporation  
P.O. Box 101, Kwangwhamun  
Seoul

Korean Stock Book Centre  
P.O. Box 34  
Yeoido  
Seoul

MALAYSIA  
University of Malaya Cooperative  
Bookshop, Limited  
P.O. Box 1127, Jalan Pantai Baru  
59700 Kuala Lumpur

MEXICO  
INPOTEC  
Apartado Postal 22-860  
14060 Tlalpan, Mexico D.F.

NETHERLANDS  
De Lindeboom/InOr-Publikaties  
P.O. Box 202  
7480 AE Haaksbergen

NEW ZEALAND  
ERSCO NZ Ltd.  
Private Mail Bag 99914  
New Market  
Auckland

NIGERIA  
University Press Limited  
Three Crowns Building Jericho  
Private Mail Bag 5095  
Ibadan

NORWAY  
Narvesen Information Center  
Book Department  
P.O. Box 6125 Etterstad  
N-0602 Oslo 6

PAKISTAN  
Mirza Book Agency  
65, Shahrah-e-Quaid-e-Azam  
P.O. Box No. 729  
Lahore 54000

PERU  
Editorial Desarrollo SA  
Apartado 3824  
Lima 1

PHILIPPINES  
International Book Center  
Suite 1703, Cityland 10  
Condominium Tower 1  
Ayala Avenue, H.V. dela  
Costa Extension  
Makati, Metro Manila

POLAND  
International Publishing Service  
Ul. Piekna 31/37  
00-677 Warszawa

For subscription orders:  
IPS Journals  
Ul. Okrezna 3  
02-916 Warszawa

PORTUGAL  
Livraria Portugal  
Rua Do Carmo 70-74  
1200 Lisbon

## SAUDI ARABIA, QATAR

Jarir Book Store  
P.O. Box 3196  
Riyadh 11471

SINGAPORE, TAIWAN,  
MYANMAR, BRUNEI  
Gower Asia Pacific Pte Ltd.  
Golden Wheel Building  
41, Kallang Pudding, #04-03  
Singapore 1334

SOUTH AFRICA, BOTSWANA  
For single titles:  
Oxford University Press  
Southern Africa  
P.O. Box 1141  
Cape Town 8000

For subscription orders:  
International Subscription Service  
P.O. Box 41095  
Craighall  
Johannesburg 2024

SPAIN  
Mundi-Prensa Libros, S.A.  
Castello 37  
28001 Madrid

Libreria Internacional AEDOS  
Consell de Cent, 391  
08009 Barcelona

SRI LANKA AND THE MALDIVES  
Lake House Bookshop  
P.O. Box 244  
100, Sir Chittampalam A.  
Gardiner Mawatha  
Colombo 2

SWEDEN  
For single titles:  
Fritzes Fackboksforetaget  
Regeringsgatan 12, Box 16356  
S-106 47 Stockholm

For subscription orders:  
Wennergren-Williams AB  
P.O. Box 1305  
S-171 25 Solna

SWITZERLAND  
For single titles:  
Librairie Payot  
Case postale 3212  
CH 1002 Lausanne

For subscription orders:  
Librairie Payot  
Service des Abonnements  
Case postale 3312  
CH 1002 Lausanne

THAILAND  
Central Department Store  
306 Silom Road  
Bangkok

TRINIDAD & TOBAGO  
Systematics Studies Unit  
#9 Watts Street  
Curepe  
Trinidad, West Indies

UNITED KINGDOM  
Microinfo Ltd.  
P.O. Box 3  
Alton, Hampshire GU34 2PG  
England

ZIMBABWE  
Longman Zimbabwe (Pvt) Ltd  
Tourle Road, Ardennue  
P.O. Box ST 125  
Southerton  
Harare



## Recent World Bank Discussion Papers (continued)

- No. 256 *Women's Health and Nutrition: Making a Difference.* Anne Tinker, Patricia Daly, Cynthia Green, Helen Saxenian, Rama Lakshminarayanan, and Kirrin Gill
- No. 257 *Improving the Quality of Primary Education in Latin America: Towards the 21st Century.* Lawrence Wolff, Ernesto Schiefelbein, and Jorge Valenzuela
- No. 258 *How Fast is Fertility Declining in Botswana and Zimbabwe?* Duncan Thomas and Ityai Muvandi
- No. 259 *Policies Affecting Fertility and Contraceptive Use: An Assessment of Twelve Sub-Saharan Countries.* Susan Scribner
- No. 260 *Financial Systems in Sub-Saharan Africa: A Comparative Study.* Paul A. Popiel
- No. 261 *Poverty Alleviation and Social Investment Funds: The Latin American Experience.* Philip J. Glaessner, Kye Woo Lee, Anna Maria Sant'Anna, and Jean-Jacques de St. Antoine
- No. 262 *Public Policy for the Promotion of Family Farms in Italy: The Experience of the Fund for the Formation of Peasant Property.* Eric B. Shearer and Giuseppe Barbero
- No. 263 *Self-Employment for the Unemployed: Experience in OECD and Transitional Economies.* Sandra Wilson and Arvil V. Adams
- No. 264 *Schooling and Cognitive Achievements of Children in Morocco: Can the Government Improve Outcomes?* Shahidur R. Khandker, Victor Lavy, and Deon Filmer
- No. 265 *World Bank – Financed Projects with Community Participation: Procurement and Disbursement Issues.* Gita Gopal and Alexandre Marc
- No. 266 *Seed Systems in Sub-Saharan Africa: Issues and Options.* V. Venkatesan
- No. 267 *Trade Policy Reform in Developing Countries since 1985: A Review of the Evidence.* Judith M. Dean, Seema Desai, and James Riedel
- No. 268 *Farm Restructuring and Land Tenure in Reforming Socialist Economies: A Comparative Analysis of Eastern and Central Europe.* Euroconsult and Centre for World Food Studies
- No. 269 *The Evolution of the World Bank's Railway Lending.* Alice Galenson and Louis S. Thompson
- No. 270 *Land Reform and Farm Restructuring in Ukraine.* Zvi Lerman, Karen Brooks, and Csaba Csaki
- No. 271 *Small Enterprises Adjusting to Liberalization in Five African Countries.* Ron Parker, Randall Riopelle, and William F. Steel
- No. 272 *Adolescent Health: Reassessing the Passage to Adulthood.* Judith Senderowitz
- No. 273 *Measurement of Welfare Changes Caused by Large Price Shifts: An Issue in the Power Sector.* Robert Bacon
- No. 274 *Social Action Programs and Social Funds: A Review of Design and Implementation in Sub-Saharan Africa.* Alexandre Marc, Carol Graham, Mark Schacter, and Mary Schmidt
- No. 275 *Investing in Young Children.* Mary Erming Young
- No. 276 *Managing Primary Health Care: Implications of the Health Transition.* Richard Heaver
- No. 277 *Energy Demand in Five Major Asian Developing Countries: Structure and Prospects.* Masayasu Ishiguro and Takamasa Akiyama
- No. 278 *Preshipment Inspection Services.* Patrick Low
- No. 279 *Restructuring Banks and Enterprises: Recent Lessons from Transition Countries.* Euroconsult and Centre for World Food Studies
- No. 280 *Agriculture, Poverty, and Policy Reform in Sub-Saharan Africa.* Kevin M. Cleaver and W. Graeme Donovan
- No. 281 *The Diffusion of Information Technology: Experience of Industrial Countries and Lessons for Developing Countries.* Nagy Hanna, Ken Guy, and Erik Arnold
- No. 282 *Trade Laws and Institutions: Good Practices and the World Trade Organization.* Bernard M. Hoekman
- No. 283 *Meeting the Challenge of Chinese Enterprise Reform.* Harry G. Broadman



THE WORLD BANK  
A partner in strengthening economies  
and expanding markets  
to improve the quality of life  
for people everywhere,  
especially the poorest

**Headquarters**

1818 H Street, N.W.  
Washington, D.C. 20433, U.S.A.

Telephone: (202) 477-1234  
Facsimile: (202) 477-6391  
Telex: MCI 64145 WORLDBANK  
MCI 248423 WORLDBANK  
Cable Address: INTBAFRAD  
WASHINGTONDC

**European Office**

66, avenue d'Iéna  
75116 Paris, France

Telephone: (1) 40.69.30.00  
Facsimile: (1) 40.69.30.66  
Telex: 640651

**Tokyo Office**

Kokusai Building  
1-1 Marunouchi 3-chome  
Chiyoda-ku, Tokyo 100, Japan

Telephone: (3) 3214-5001  
Facsimile: (3) 3214-3657  
Telex: 26838



ISBN 0-8213-3229-5