A Conceptual Framework for Economic Evaluation of Desert Locust Management Interventions

Bernd Hardeweg

A Publication of the Pesticide Policy Project
Hannover, February 2001

Special Issue Publication Series, No. 5

Pesticide Policy Project Publication Series
Special Issue No. 5, February 2001

Institut für Gartenbauökonomie,
Universität Hannover
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

A Conceptual Framework for Economic Evaluation of Desert Locust Management Interventions

Editors of the Pesticide Policy Project Publication Series:

Prof. Dr. H. Waibel
Institut für Gartenbauökonomie
Universität Hannover
Herrenhäuser Str. 2
30419 Hannover
Germany
Tel.: +49-(0)511-762-2666
Fax: +49-(0)511-762-2667
E-Mail: waibel@ifgb.uni-hannover.de

Dr. C. Henckes
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Abt. 4543
Postfach 5180
65726 Eschborn
Germany
Tel.: +49-(0)6196-791411
Fax: +49-(0)6196-791115
E-Mail: christian.henckes@gtz.de

Publication of the Institute of Horticultural Economics,
Herrenhäuser Str. 2, D-30419 Hannover

Printing: Uni Druck Hannover, D-30419 Hannover

ISBN: 3-934373-05-4

The difficulty lies not in new ideas,
but in escaping from old ones.

(John Maynard Keynes)

Preface

The desert locust is an ancient problem. People in Africa, the Middle East and parts of Asia had to live and cope with it for many centuries. It is only with the development of chemical pesticides that man developed the belief he could solve this problem by adopting a strategy of war against nature. Spraying poisonous pesticides to combat locust swarms became an approach which was highly spectacular. Locust outbreaks quickly made the political action threshold to become surpassed and stimulated governments for intervention. By adopting a strategy of early control national governments often supported by FAO, were able to demonstrate to their people that they are doing something. Consequently, for a long time large sums of money were spent to buy pesticides and offer them as aid to developing countries. It became more and more impossible for decision-makers in development and donor agencies to deny a request for support to fight off locusts. Wouldn't it be unethical to even question the justification for support when being faced with the picture of terrifying locust swarms eating up the hard work of poor farmers in just a matter of hours? Disasters rightly create compassion and sympathy was the main driving force in providing funds for support. Hence asking the question whether locust control campaigns really pay off, for a long time simply was an irrelevant question. Unfortunately *sympathy* has gradually and steadily developed into *subsidy* and the distinction between the two has become blurred.

With the advancement of a better scientific understanding on the desert locust problem and as the negative effects of chemical pesticides became more widely known the situation began to change. Today, financial support for dessert locust control is a controversial issue in international development circles. It has come to a point where the popular phrase of "more research is needed before we can make further decisions" was no longer enough. For a very long time, data have been collected and modeling exercises were performed. Yet very little could be said on whether the resources spent are justifiable.

It is here where the research of Bernd Hardeweg, a young and promising economist of the University of Hannover, on the Economics of Desert Locust Management fills an important gap. His most important contribution is the rigorous attempt to overcome the "language of loss" which for such a long time has dominated the debate. His study offers a way to bring efficiency considerations back to the front seat. He also tackles the important question of how to treat risk in an analytical and not in an emotional way and also dwells upon the political economy of desert locust control in an innovative and readily accessible way. The book should create enough appetite for conducting case studies validating the approach prescribed and to search for better avenues to handle the desert locust problem.

Hermann Waibel

Department of Economics

Hannover University

Germany

Acknowledgements

This study was initiated by the Desert Locust Management project of GTZ and commissioned to Hannover University when Dr. Stephan Krall was in charge of the project. I would like to thank Prof. Dr. Hermann Waibel and Dr. Gerd Fleischer for introducing me to this fascinating topic while I was completing my MSc degree. For their willingness to share and discuss their views I am deeply indebted to them.

I would like to thank Matthias Zweigert of GTZ for his continued interest and support as well as his patience during the extensive gestation period of the manuscript.

Furthermore, I would like to thank all the participants of the desert locust economics meeting on June 28-30, 2000, at FAO in Rome, Prof. Dr. El-Bashir, Dr. M. Belhaj, K. Cressman, Dr. N. v.d. Graaff, Dr. C. Pantenius, Dr. D. Vanzetti and M. Zweigert for their critical as well as supporting comments on an earlier version.

The draft was thoroughly examined by Dr. B. Zelazny, a distinguished desert locust expert, whose comments improved my knowledge on desert locust control in general and the accuracy of technical terms in particular. The draft underwent similar rigor in checking by my colleagues Dr. Bezabih Emana and Diemuth Pemsl. Their comments were of great help and formed an important contribution to the revision. To them I owe gratitude for sharing their views and knowledge and for their valuable inputs to this edition. Thanks go also to Imke Panschow, who took care of layout and printing and was very patient with the last changes. They all helped to weed out many errors and mistakes and to improve the readability of my English. Of course, all remaining errors have to be blamed on me.

Bernd Hardeweg

February 2001

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CBA	cost-benefit analysis
CDF	cumulative distribution function
CE	certainty equivalent
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement, Montpellier
CVM	contingent valuation method
DCU	domestic currency units
EMPRES	Emergency Prevention System (EMPRES) for Trans-boundary Animal and Plant Pests and Diseases at FAO
FAO	Food and Agriculture Organization of the United Nations, Rome
GTZ	Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn (Germany)
IPM	integrated pest management
NGO	non-governmental organization
NPV	net present value
SER	shadow exchange rate
WTA	willingness to accept
WTP	willingness to pay

1 Introduction

1.1 Background

Desert locusts (*Schistocerca gregaria*) are the classical case of a migratory pest. Being a spectacular natural phenomenon this insect species has attracted the attention of mankind since ancient days as reports of plagues in the Koran and the Bible show. Although desert locusts live as solitarious individuals in remote and non-agricultural areas most of the time, they can rapidly reproduce under favorable conditions and change to their gregarious phase. They form hopper bands and huge swarms of flying adults. The latter can travel remarkable distances and feed on virtually all parts of plants, which makes them an unpredictable threat to agricultural production.

The risk of crop losses has prompted governments of the affected countries ranging throughout the Sahel, Northern Africa and the Middle East to Pakistan and India to conduct emergency control interventions. In order to reduce the costs of control operations and to improve the effectiveness of protection measures, national governments together with FAO as a coordinating agency, have implemented projects or programs of early control[1].

This strategy is based on monitoring desert locust populations in their breeding habitats and controlling them with chemical pesticides before the critical population size for gregarization is attained. Unfortunately, many important breeding habitats are located in geographically remote and inaccessible areas, which increases monitoring and control costs. Furthermore, civil unrest and war in the last decades were major obstacles to successful early control in countries like Eritrea, Ethiopia and Sudan, where important breeding habitats are situated.

Over time, governments of the affected countries as well as donors and aid organizations have devoted considerable efforts and financial resources to combating this pest. Global expenditures for desert locust control have exceeded US$ 500 million in the ten year period from 1987 to 1996 (JOFFE,

---

1 Throughout the text, the term *project* is used instead of *program* because it is generally used when referring to a specific intervention strategy. The term has been adopted from literature on cost-benefit analysis and is used here not only to refer to *aid projects* but to any public investment for a strategy which is undertaken to gain benefits for a usually clearly defined group.

1998). Donor contributions to preventive and reactive control are estimated at US$ 300 million in the 1986-1989 campaign alone (SCHROEDER, 1999).

In spite of the considerable utilization of public funds, economic studies of desert locust control efforts have remained surprisingly scarce. An exception is JOFFE (1998) who presented the most recent and most comprehensive study on the economics of current control interventions. He must be commended for providing useful insights to the desert locust problem from an economic point of view despite an extremely sparse data environment. In his analysis, positive net benefits from control accrue only with a likelihood of 10 to 20 %. Accordingly, average costs exceed benefits in the order of US$ 10-24 million annually. External costs of pesticide use are not included in these figures (JOFFE, 1998). The study was heavily criticized among locust control specialists and therefore largely failed to strengthen the economic argument in the assessment of desert locust control programs.

Governments of affected countries, aid organizations and donors have strong interest to efficiently allocate scarce funds. Thus, there is a demand for economic evaluation of proposed interventions. With increasing demand for transparency in decision-making and the bargaining power of interest groups effective and convincing communication is a precondition to implement desired strategies. Such bargaining processes can become more efficient if they are based on sound economic analysis. Especially with regard to the rising concern about the environmental side-effects of heavy pesticide use, objective and quantitative information is needed to trade off benefits of control with negative environmental effects as well as health hazards for humans and livestock.

This book intends to contribute to the process of improved decision-making by assembling a framework for data collection and analysis that is capable of integrating the multiple dimensions of the desert locust problem. It not only compiles the necessary methodology but also aims at presenting an analytical concept that is based on welfare economic theory to relevant decision-makers and locust control specialists. One of the aims of this conceptual framework is to contribute to a common basis for communication between economists and plant protection specialists. It shall thus provide a starting point for more targeted data collection, analysis and decision-making.

The remainder of this introductory chapter provides some background information on the history of the current control strategy and presents a simplified example of the analytical approach used in previous evaluation studies. It concludes with a number of critical remarks on the methodology.

With respect to this critique, in chapter two the conceptual frame for an improved basis for decision-making is developed. This involves broadening the scope from the “spray/no spray” paradigm to a number of alternative intervention strategies. It also presents the basic economic concepts that support a more rational approach to the desert locust problem by treating it in analogy to other sources of risk in agricultural production. Chapter three develops this concept in concrete terms and presents analytical concepts for farm and national levels as well as considerations on supranational issues. The appropriate methodology for data collection and analysis is described in chapter four, including farm budget analysis, the contingent valuation method and methods for obtaining data on risky parameters. Chapter five presents a simple example demonstrating an application of the concept. The conceptual framework is applied to evaluate the hypothetical desert locust management in “Africaland”. The salient points of the new concept and recommendations for further investigation are summarized before the book closes with a summary in chapter seven. Finally, a glossary of predominantly economic terms and an appendix containing more detailed discussions of selected issues are provided.

1.2 The current control policy – a brief history and major issues

A strategy of early control has been promoted by FAO since about 30 years ago (CHARA, 1997). It aims at controlling all gregarizing or numerically large desert locust populations in order to prevent outbreaks, upsurges and plagues[2]. To achieve this goal, monitoring of rainfall, vegetation and soil moisture in the seasonal breeding areas is carried out. Additionally, suitable breeding habitats are regularly surveyed. Whenever the observed population densities exceed certain thresholds, control of gregarious or gregarizing locusts is effected (JOFFE, 1995). In theory, these thresholds mark the transition from the solitarious to the gregarious phase and are not derived from economic considerations. In practice, however, every swarm of desert

---

[2] **outbreak**: a marked increase in locust numbers due to concentration, multiplication or gregarization which, unless checked, can lead to the formation of hopper bands and swarms
upsurge: a period following a recession marked initially by a very large increase in locust numbers and contemporaneous outbreaks followed by the production of two or more successive seasons of transient-to-gregarious breeding in complimentary seasonal breeding areas in the same or neighboring desert locust regions.
plague: a period of one or more years of widespread and heavy infestations, the majority of which occur as bands or swarms. A major plague exists when two or more regions are affected simultaneously (FAO, 1999).

locusts is actively combated, irrespective of the remoteness of their habitat and the likelihood to inflict damage on cropped land (HEROK and KRALL, 1995). On the other hand, many areas are left out from proper control due to lack of funding, war and civil conflict or negligence.

The efficacy of the current control strategy is subject to a controversial discussion. CHARA (1997) as well as MBODJ and LECOQ (1997) claim that the experience of the last 30 years has proven early control strategies to be an effective means for protecting crops from desert locust damage. Further, CHARA (1997) asserts that outbreak and upsurge control are clearly the minimum cost alternative and cause no harm to the environment. However no data are provided to support this claim.

Other authors, on the contrary, cast doubt on the technical efficacy of the present control strategy. JOFFE (1995) gives several reasons for the rapid decline of the plague in 1988/1989, with active control being only one of them. However, he does not judge the relative importance of the control campaigns. A study by CIRAD conjectures that 20% of the locust populations destroyed in 1988/1989 can be attributed to control efforts, while 30% where blown out on the Atlantic, 30% were killed by low temperatures and another 20% died because of insufficient rainfall (MAGOR, 1989).

According to HEROK and KRALL (1995) recent outbreaks show that control campaigns are not sufficiently effective. They even state that “without exception, all observed plagues have run their course and ceased without human intervention” (HEROK and KRALL 1995, p. 48). The economic efficiency of the current strategy has been questioned by the studies of HEROK and KRALL (1995) and JOFFE (1998), even though they exclude health costs and losses in production likely to be incurred by pastoralists.

Another problem as pointed out by KREMER (1992) is that for countries like Mali, Burkina Faso, Niger and Senegal continued funding of desert locust control is out of sight.

Only limited evidence has been presented for the field performance of control measures. There is hardly any data showing the relationship between the reduction of desert locust populations by control measures and the resources used[3]. The FAO “Desert Locust Guidelines” (SYMMONS and CRESSMAN, 1992) did not emphasize comprehensive campaign evaluation. A draft of a sixth

---

3 JOFFE (1998) draws for his simulation on an unpublished summary study produced by HARVEY (1997) that uses data on control costs and efficacy from eight countries (Algeria, Eritrea, Mali, Mauritania, Morocco, Saudi Arabia, Sudan and Yemen) specially prepared for this purpose.

part of the "Desert Locust Guidelines" of FAO focusing on campaign evaluation (MCCULLOCH, unpublished), which was prepared several years ago, proposes a scheme for analysis that focuses on campaign effectiveness in terms of desert locust population killed. It is thus constrained to technical efficiency at the site of application, ignoring the relationship between the effectiveness of control measures in remote areas and potential damage on cropped land. Technical efficiency of control campaigns, however, should be assessed with regard to the crop damage prevented, which is the ultimate goal of control interventions. Even if data had been gathered along the proposed guidelines, their value for economic analysis would be limited.

A further issue is the integration of chemical control activities into an integrated pest management (IPM) framework (JOFFE, 1995). IPM is the state of the art in pest management and comprehensively defined as "a crop protection system which is based on rational and unbiased information leading to a balance of non-chemical and chemical components moving pesticide use levels away from their present political optimum to a social optimum defined in the context of welfare economics" (WAIBEL and ZADOKS 1996, p. ii).

As a consequence of this comprehensive approach, detailed insight into the ecological and economic processes and interdependencies is necessary. JOFFE (1995) identifies a number of fields where the lack of knowledge impedes an integrated pest management approach in desert locust control: population dynamics, the probability of attacks in given production systems, crop losses, and the economic impacts of the lost production as well as alternative control strategies. In a review study LOMER et al. (1999) provide an overview of the opportunities and constraints of integrating biological control agents into locust management schemes.

1.3 Economic evaluation – an example

HEROK and KRALL (1995) and JOFFE (1998) point out some of the difficulties for the economic evaluation of desert locust control. An example following basically the *ex post* evaluation approach of control operations in Morocco is taken as a case study, because some data are available from the above mentioned evaluation studies. Morocco is located in the northwest of the western desert locust region. Only a small part in the south belongs to the recession area, while the rest of the country belongs to the invasion area (STEEDMAN, 1990). Under plague conditions, Morocco is likely to be invaded from the south via the border to Mauritania during August to January and from the north west (Algeria) during March to June (MAGOR, 1993).

Morocco is one of the Maghreb countries for which preventive control has been proposed as a control strategy by FAO in 1988 (HUIS, 1993). Unlike in some other countries, desert locust control operations are well organized and can draw on considerable resources so that it can be assumed that functioning control is actually in effect (JOFFE 1995, p. 21).

The model of JOFFE (1998) measures the benefits of control efforts in terms of prevented yield losses by comparing the (hypothetical) scenario of inaction to a scenario with effective control of desert locust populations. Table 1 gives the annual production losses in absolute values and as percentage of total crop production. These figures were obtained from a model of desert locust population dynamics, control effectiveness and crop losses. Further, base prices and demand elasticities are assumed for the listed commodity aggregates to allow for price reactions to changes in commodity supply (see 3.5.3 on p. 65 for the detailed methodology). The data reflect a long term average damage scenario, i.e. including the recession and plague conditions.

Table 1: Annual crop loss in Morocco due to desert locusts in an average damage scenario

Commodity	Mean losses[1]	Share of production	Base price[2]	Demand elasticity[2]	Price after crop damage	Value of lost production	Consumer losses	Producer gains	Net losses
	[t]	%	$/t		$/t	1,000 $	1,000 $	1,000 $	1,000 $
Millet, sorghum	290	0.24	125	-0.26	126	36	139	103	36
Wheat, barley	15,965	0.47	137	-0.15	141	2 187	14,547	12,325	2,222
Maize	2,300	0.69	121	-0.20	125	278	1,387	1,104	283
Fruits and nuts	13,858	0.54	433	-0.50	438	6 001	11,969	5,936	6,033
Other fruits and vegetables	3,179	0.38	193	-0.50	194	614	1,225	609	616
Pulses, oilseeds	331	0.87	395	-0.50	402	131	260	128	132
Cotton	177	0.68	742	-0.50	752	131	262	130	132
Total									**9,454**

Quantities in metric tons, prices in 1990 US$

Sources: [1]Economics of Desert Locust Simulator (JOFFE 1998, p. 46)
[2]World Food Model (cited in JOFFE 1998, p. 46)

On average, desert locusts inflict damage to Morocco's crop production that accounts for economic losses of roughly US$ 9.5 million per year (Table 1). Assuming that control campaigns can completely prevent these losses, this is the gross benefit of control.

The fixed costs of an early control framework consist of the public expenditures for the purchase and maintenance of equipment, salaries of permanent staff, costs of research, development and training, and contributions to regional organizations. The costs for pesticides, fuel and seasonal labor depend on the actual scale of necessary control campaigns. These are variable costs. The average annual costs for the period 1987 to 1996 are given in Table 2.

Table 2: Average annual costs of desert locust control in Morocco

	Annual expenditures in 1 000 US$		**Sums**
Farmers		not specified	
Government	Depreciation of equipment	not specified	
	Wages and salaries	not specified	
	Contributions to supranational institutions	not specified	
	Total fixed costs	2,773	2,773
	Pesticides	6,520	
	Fuel etc.	not specified	
	Seasonal labor	not specified	
	Medical costs (staff only)	398	
	Total variable costs	10,097	10,097
	Government total costs		**12,870**
Society at large	Health hazards	not available	
	Production losses	not available	
	Environmental damage	not available	

Calculated from data for 1987-1996, costs in 1990 US$.
Sources: JOFFE (1998)

As Table 2 shows, government expenditures are partially known. External costs through health hazards for the public, production losses, e.g. in livestock production and costs of environmental damage have not been quantified. Due to data limitations, costs were calculated as average annual values.

Comparing benefits and costs reveals that costs exceed benefits by about US$ 3.4 million on average. It is obvious that on average, control is uneconomic in the case of Morocco.

Why then do decision-makers stick to desert locust control? Two main lines of reasoning may answer this question. Firstly, it is possible that decision-makers base their decisions on other criteria than economic efficiency. Actually, a number of authors agree that desert locust damage creates political pressure within affected countries and the donor community to intervene irrespectively of economic considerations (HUIS 1993, p. 12; JOFFE 1995, p. ix; KREMER 1992; LOMER et al. 1999; POTTER and SHOWLER 1991, p. 153). This may be an explanation for the observed deviation of decisions from economic performance criteria.

Secondly, the analysis may not capture the problem appropriately. One could argue that a simplistic approach as the one presented above cannot yield satisfactory insight into the problem. The main constraints are as follows:

- The analysis is based on mean values only. As decision theory shows, risk averse decision-makers are prepared to pay a premium to avoid uncertain outcomes or high variances. Desert locust damage is randomly distributed with regard to time, place and severity of incidence. The stochastic dimension of the problem should be integrated into economic analysis[4].
- Benefits are calculated in terms of crop loss prevented by control campaigns. Such an approach however ignores the farmers' own adaptation measures in spite of their distinct welfare repercussions. Taking a scenario of complete inaction as reference scenario is unlikely to be realistic for market economies where allocation decisions are decentralized. On the one hand this approach will lead to an overestimation of control benefits and on the other hand, strategies focusing on the farmer community, e.g. crop insurance, cannot be captured within this framework.
- Cost categories not directly related to survey and control operations are neglected. These costs comprise environmental and health costs resulting from direct contamination and food residues as well as losses in livestock production accruing to pastoralists. To obtain a true representation of social welfare effects these costs must be included in the analysis.

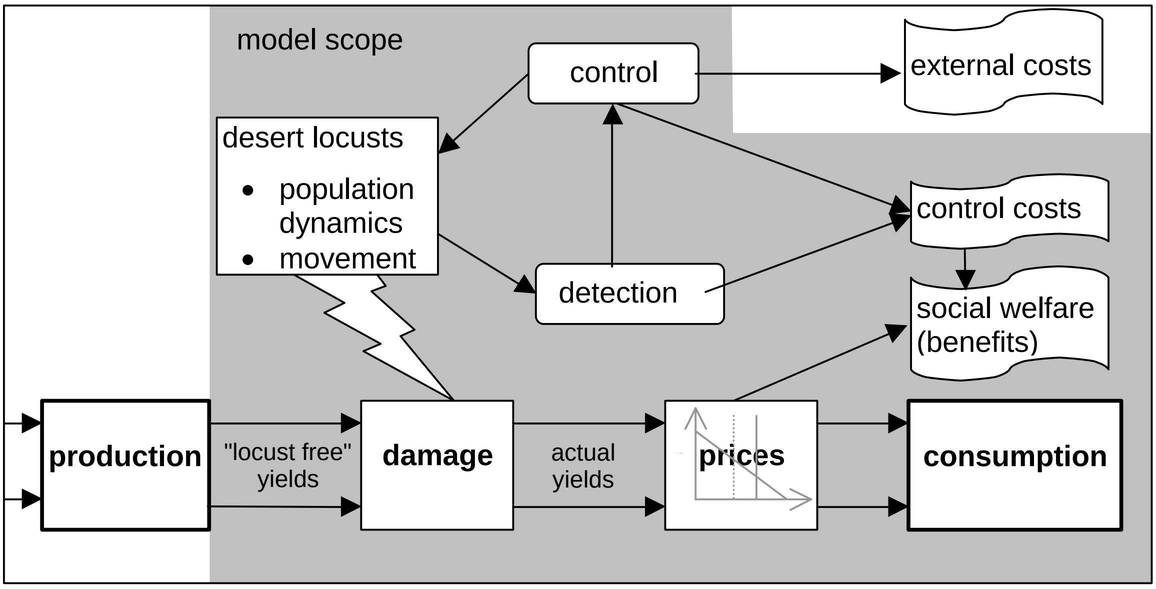
4 JOFFE (1998) takes into account the stochastic distribution of locust populations, damage and costs and benefits of control. The results are presented in Figure 2 on p. 17.

- Finally, it must be stressed that the economic analysis presented above is based on the presupposition that control campaigns are an effective means to reduce the risk of crop loss and food insecurity from desert locusts.

Risk considerations could explain why decision-makers stick to strategies that come at net costs. Control strategies are chosen if decision-makers are risk averse and it is assumed that control has a risk reducing effect. All other shortcomings of the evaluation methodology listed above lead to an overestimation of benefits, or to an underestimation of costs, respectively. An evaluation that takes the listed objections into account would therefore result in even higher net costs than the presented method.

Figure 1 visualizes these conclusions. The shaded area represents the scope of the underlying model. Farm production is taken as a given fact independent from public intervention and is not considered explicitly in the model except for its outputs, i.e. the yield level without desert locust damage. Locust damage on the other hand, is modeled as a function of desert locust population dynamics and movement. The remaining agricultural outputs are fed into a market model that considers price elastic demand and yields benefit estimates for different supply scenarios. Monitoring and control of locust populations are the only interventions considered. They interact with the desert locust population by detection rates and control effects. The on-site costs of the strategy are accounted for in the model while external costs are omitted.

Figure 1: Basic structure of the Economics of Desert Locust Simulator used by JOFFE



Source: own presentation after JOFFE (1998)

Comparing Figure 1 and Figure 3 on p. 31 reveals the main differences and advancements of the methodology proposed in the following chapters.

2 From economics of control to desert locust management

2.1 Components of desert locust management assessment

It is necessary to extend the range of evaluation alternatives from different control options to a more comprehensive set of management options. Therefore, the term *desert locust management* will be used to mark this broadened scope. In order to identify possible approaches, this section dwells upon a thorough problem analysis from an economic perspective.

2.1.1 Desert locusts as a public bad

In economics, goods and services are classified as public and private goods according to two characteristics: rivalry and excludability. A good is considered a pure public good if its consumption is non-rival and non-excludable, meaning that the consumption of one person does not reduce another person's consumption and that the good is available to all, respectively. As a consequence, public goods should be provided free of charge (HANLEY et al. 1997, pp. 42f). By analogy, a public bad is a source of disutility that is shared by many persons, who cannot be readily excluded from the disutility the public bad imposes.

> **FOCUS: "PUBLIC PESTS"**
>
> KREMER (1992) as well as HOUNDEKON and DE GROOTE (1998) classify desert locusts as a "public pest". Public pests must be combated before they are in the crop, because once they are there, it is too late for abatement. They conclude that this kind of pest calls for public intervention.
>
> Can the concept of a public bad capture the economic features of a public pest? In what cases is public intervention justified?

Desert locusts are a case of such a public bad. A large number of farmers can be affected at a time and they cannot be readily excluded from the damage. The claim for public intervention is usually based on this notion of a "public pest" (HOUNDEKON and DE GROOTE, 1998; KREMER, 1992).

However, this is not necessarily a cogent argument. Farmers can – in principle – protect their crop mechanically from a locust invasion, e.g. by covering their crops with nets[5]. Thus, the farmer can herself/himself exclude from the public bad and thus public intervention is not necessary. This

---

[5] It is understood, though, that such costly protection measures have a potential rather under exceptional conditions.

solution can be brought about by the market. As the farmer receives the benefits from its application, he will have an incentive to increase the area protected by the net, as long as the additional benefits from the prevented losses outweigh the additional costs[6].

The same is true for other strategies. The farmer would also be ready to contribute to the implementation of a desert locust control strategy, but only as long as his additional private benefits exceed the additional costs. At the same time, other farmers gain from a public control strategy, since there is no rivalry in consumption of the good and they cannot be excluded from the benefits of public control, i.e. given a noticeable effect of public control they will experience fewer desert locust invasions even without paying. Public control in its presently practiced form has to be regarded as a public good, because it is provided free of charge by governments and donor organizations.

Due to non-excludability, there is an incentive for individuals to hide their true willingness to pay in the hope of enjoying the benefits of the public good paid for by others. This is referred to as the free-rider problem of public goods: those who do not pay cannot be excluded from enjoying the benefits. The benefits from a unit of a public good accrue not only to one individual but to all individuals of the society – or in the case of desert locust control to at least to all farmers. The social benefit of one unit is, therefore, the cumulative utility of all individuals and the socially optimal level of supply is attained when marginal production costs equal the *sum* of the individuals' willingness to pay (MISHAN, 1994). Finally, this is the reason why government intervention can have welfare improving effects: if the social benefit from public control exceeds private benefits, leaving control to private markets would supply the good in sub-optimal quantities.

A social cost-benefit analysis (CBA) provides the means for determining the socially optimal level of provision of the public good from the viewpoint of economic efficiency (MISHAN, 1994). But the absence of a market for public control means also an absence of prices. There is no straightforward approach to measuring the utility that individuals derive from public control. The lack of a market price for "public" desert locust control poses difficulties for the assessment of benefits.

---

[6] This holds true only if the farmer is risk neutral. As farmers are often risk-averse, she or he will be ready to pay an additional risk premium to reduce the variability of income.

To date, economic studies of the currently pursued strategy have relied on the value of prevented damage (physical loss times price) as a benefit estimate (HEROK and KRALL, 1995; JOFFE, 1998). However, in some cases the crop could recover from physical damage or farmers would be able to react to a desert locust invasion, e.g. by replanting. The economic loss would be lower than the physical loss times price. Also alternative strategies are not accounted for, which would have a potential to reduce the damage in the absence of control interventions. The available CBA studies, therefore, overestimate the benefits. An analytical framework that seeks to avoid this problem is developed in chapter 3.

So far, public control has been considered as a public good to farmers. It is also a public good beyond the boundaries of national economies. The strategy is actually built on the assumption that combating locust populations anywhere even in remote and barren areas reduces the invasion of swarms on farmers' fields. It is further assumed that controlling populations in the important breeding habitats, e.g. around the coast of the Red Sea or in Mauritania is more efficient than controlling swarms on invasion of cropped land (KRALL, 1994). As a consequence, free riding could be a problem among countries, too, because there are international externalities.

Externalities are economic effects of one agent's behavior on another's well-being, where the effect is not reflected in market transactions (LITTLE and MIRRLEES, 1974). Here, public services in one country, e.g. Eritrea, provide the good "desert locust control" and other countries, e.g. Sudan, benefit because they would have been invaded otherwise. This is what economists call positive externalities. Goods that carry positive "international externalities" may be produced on a globally sub-optimal level. The country that "produces" public control cannot capture all the benefits. This provides the rationale for an intervention of supra-national bodies and international organizations, because they can help internalizing such external effects. This could be necessary when countries covering important breeding habitats have no stake in expensive control operations on their territory, because their crop value at risk is too low, whereas other countries derive high benefits from control in the breeding habitats. An example of such a bilateral arrangement is Morocco's support of control operations in Mauritania.

Yet there are also negative external effects of desert locust control, i.e. costs perceived by agents not involved in the decision process. These result from the application of chemical pesticides, which have notable side-effects on human and livestock health, populations of beneficial organisms and the environment in general (e.g. SHOWLER, 1999).

JOFFE (1998) acknowledges that negative externalities should be included into CBA but due to data shortages he omits this item in his calculation. But these costs are indeed recognized by the affected parties as can be seen from reports of nomads and beekeepers hampering control operations in Yemen (JOFFE, 1998). SHOWLER (1996) reports human health effects of the 1986-89 campaign in Morocco, where 1,000 staff members were removed from spray operations due to low acetylcholinesterase titers in their blood as a consequence of exposition to acutely toxic pesticides.

These examples show that besides the direct project costs for survey and control operations also external costs are caused by chemical control. In an evaluation from a social point of view, these costs must be accounted for. The difficulties of identifying, quantifying and monetarizing external effects, have put off analysts to include them in economic evaluation studies of desert locust control (HEROK and KRALL, 1995; JOFFE, 1998). However, results from available studies of pesticide externalities can be used at least as crude estimates. External costs have been found to be in the range of \$ 0.23 to \$ 2 per every \$ spent on pesticides depending on the country studied and the external cost categories included (FLEISCHER et al., 1999).

2.1.2 Identification of stakeholders

In every project planning cycle, it is important to be aware of the institutional and policy environment as well as of groups of stakeholders. This issue has so far been treated rather unsystematically. While the political pressure from crop producers has often been mentioned (see above) and their stake is immediately obvious, other affected groups are easily overlooked. For better understanding of the political background of decisions on desert locust control, it might, however, be helpful to rationalize these considerations.

> **FOCUS: STAKEHOLDERS MAKE THEMSELVES HEARD**
>
> Reports of nomads and beekeepers hampering control teams in Yemen by giving misinformation and forbidding access to their areas for control operations shows that the risk of livestock and bees being poisoned is well recognized (JOFFE, 1998). The Tunisian government has acknowledged that bee keeping is threatened by inconsiderate control operations. Pesticide spraying against locusts has been completely banned for oases due to their fragile ecosystems (POTTER and SHOWLER, 1991).

The impact of desert locust management decisions on groups like pastoralists, beekeepers, rural and urban consumers as well as exporters needs clarification. The outcome for each of the groups is not clear in advance, since they often at the same time bear costs and receive benefits. Herdsmen e.g. could benefit from better feed supply from pastures and fodder trees for their livestock when desert locusts are controlled. At the same time they may bear the costs of acute pesticide intoxication or reduced fecundity of their livestock. Similarly, the increased food supply that is expected from control interventions has to be weighed up against the health hazards that rural and urban consumers face when chemical pesticides are used. While these impacts are already difficult to capture, inter-temporal effects like long-term effects on wildlife and ecosystems even increase the complexity of the analysis. But these long-term effects are nevertheless a matter of concern among involved governments, donors and NGOs.

2.1.3 Risk

Desert locusts are often named along with other natural disasters that threaten crops in the affected countries. This is due to their erratic and sudden appearance on farmers' fields, which often results in locally severe losses.

A survey conducted in Niger in 1991 highlights how farmers perceive this threat. 57 percent of farmers named desert locusts the biggest threat to their pearl millet during their lifetime. When the question was focused on the last growing seasons, the majority cited other pests (KRALL, 1994). Desert locusts are thus considered a dangerous pest but the individual farmer experiences calamitous events only few times or once in a lifetime. This reveals that farmers attribute only a small probability to a major locust damage, while the impact of such an attack is judged as very menacing.

Another study has elicited the willingness to pay (WTP) for insurance among Ethiopian farmers (WAROLIN, 1998). In the survey, a hypothetical insurance was offered that covered the complete loss from locust damage. The annual willingness to pay for the offered insurance was US$ 2.66 per household in villages that had experienced a locust invasion within the past 6 years and only US$ 1.59 in those, which had not been attacked by locusts for a longer time. Unpublished results of surveys by BELHAJ in Morocco and Sudan indicate a willingness to pay for an insurance between US$ 8 and US$ 21 (BELHAJ, 2000). A willingness to pay for insurance indicates risk aversion. This is in line with the findings of other studies on farmers’ risk attitudes (BINSWANGER, 1980; HARDAKER et al., 1997; PANNELL, 1991).

Consequently, formal analysis has to account for farmers' attitudes to risk. The high potential damage and the low probabilities of occurrence preclude simplified deterministic approaches for an evaluation.

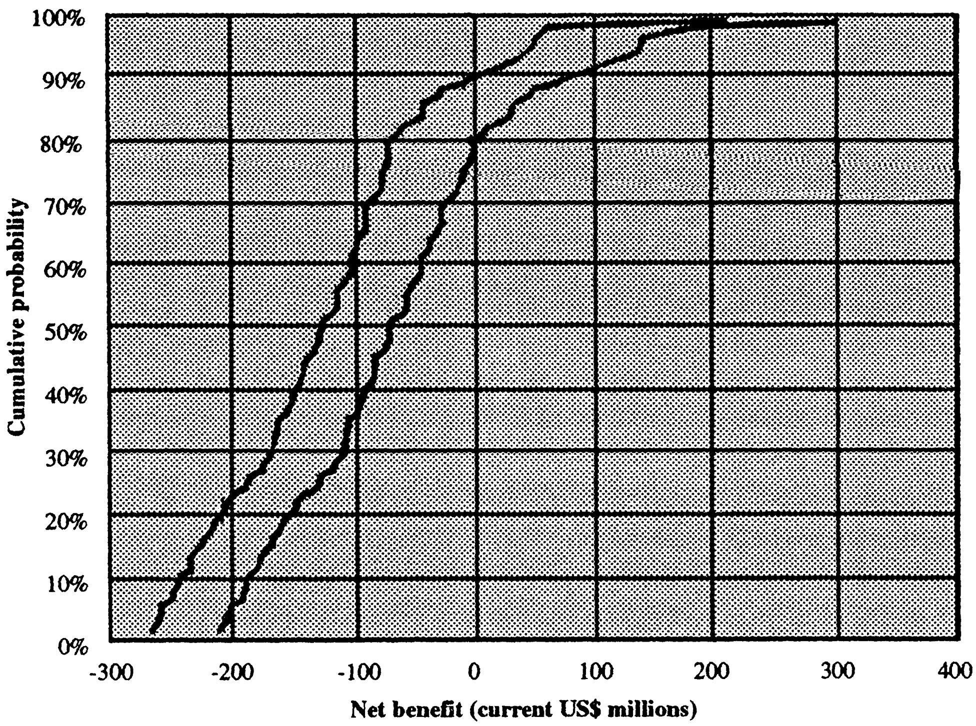
Until today risk has not been considered in the assessment of desert locust management. It seems a firm conviction that farmers' means are too restricted for a reaction to the desert locust risk and that their participation in decision-making was not necessary. This view evolves from the notion that coping with desert locusts is restricted to large scale control campaigns and that farmers' traditional methods like digging trenches and beating the hopper bands are completely ineffective (HEROK and KRALL, 1995). But on-farm coping and mitigation strategies such as the adaptation of cropping schemes must be considered in an economic analysis, because they will have distinct production effects and hence welfare consequences.

However, even if risk is recognized on the farm level, the available risk management strategies might be limited by institutional and financial constraints. This is particularly the case for many locust affected countries in the Sahel belt, where local markets are poorly integrated, private or public crop insurance or formal credit schemes are unavailable, stock keeping is extremely costly, or subsistence on marginal lands offers no buffer stock to rely on in times of crisis (JOFFE, 1998; WEBB et al., 1992). In developed countries markets provide insurance because it is profitable where risks cannot be borne by individual enterprises. The absence of commercial insurance for the risks that rural households in wide parts of the developing world face can be interpreted as a market failure.

When markets cannot provide insurance against disastrous risks, it is the task of policy makers to account for risk, e.g. for the risk of food insecurity or complete income loss of the affected households. On the other hand, relief payments, subsidized insurance programs or crop grants may not only be costly for the government but also reduce prevention measures on the side of the farmers as experience has shown (ANDERSON and DILLON, 1992; HARDAKER et al., 1997; SKEES et al., 1999). The possibility of providing insurance and the resulting benefits for the protection of the rural population should be evaluated as an alternative together with other desert locust management options.

Moreover, risk considerations are not only of concern for affected farmers but also for decision-makers on aggregated levels. Figure 2 highlights a way to represent the stochastic nature of net benefits of public control. It also indicates that the continued adherence to this strategy corresponds to an extremely risk averse behavior of the involved decision-makers. They are ready to invest in a strategy that has a negative net benefit on average. Such risk averse behavior comes at the cost of a risk premium, which was estimated from global simulations to be in the range of US$ 53 million and US$ 117 million for a 5 year period depending on assumptions for control effectiveness (JOFFE, 1998). This means that on average, costs exceed benefits in the order of US$ 10-24 million annually. Decision-makers seem to be willing to pay these net costs as a kind of insurance premium for disastrous losses, sometimes with the argument of food security[7].

Figure 2: Risk profiles of net benefits of the current control strategy



Source: JOFFE (1998), p. 50

In fact, the study of JOFFE (1998) is the first to introduce formal risk considerations into desert locust control studies. He also gives a revealing description of the practical handling of public control in stating that it "aims to destroy all dangerous populations in order to try and prevent large swarming populations or plagues developing. Dangerous is usually interpreted as meaning gregarious or gregarising populations, but is sometimes extended to

7 It has not been proven that the current control strategy is actually preventing losses on farmers' fields. It is also doubtful whether desert locust attacks can cause widespread food insecurity (KRALL, 1995).

include all numerically large populations, irrespective of their phase." (JOFFE 1998, p. 27). In other words, decision-makers on the operational level consciously or implicitly adhere to the Maximin decision rule, which effectively shows inveterate pessimism[8].

The findings of JOFFE (1998) imply that a risk neutral decision-maker should refrain from public control. However, it cannot be assumed that all decision-makers are risk neutral. Especially on farm level, village and district level decision-makers might try to minimize the variability of farmers' income and its impact of food insecurity. The presented arguments call for relevant approaches to assess the risky prospects for decision-makers on more disaggregated levels. Section 2.3 introduces some basic risk analytical tools that facilitate the discussion of this issue. The practical concept discussed in chapter 3 enables decision-makers to trade off the risky prospects of different desert locust management strategies.

2.1.4 Identification of farm level coping strategies

The simple evaluation example of section 1.3 neglects coping strategies available to farm enterprises and households. However, farmers might have the choice among risk containment and coping strategies besides locust control. The evaluator should not overlook the impact of these private protection measures. A list of general coping strategies is given below.

Diversification

By choosing a greater number of different production activities, the farmer can simply reduce overall income variance. When the returns on these activities are negatively correlated, the risk reducing effect is further enhanced. Typically, in dryland farming systems, the returns on different cropping activities will be positively correlated, because e.g. all crops are affected by drought. This is true for desert locust damage, too. But members of the farm-household could additionally engage in off-farm income generating activities, which are – at least to some extent – independent of the performance of the farming activities (ANDERSON and DILLON, 1992). The importance of those off-farm incomes is stressed by WEBB et al. (1992), who also point out the dependencies of off-farm activities on the performance of the farm sector in semi-subsistence areas. The remittances of workers in

[8] The Maximin rule selects the alternative with the highest payoff in the worst possible outcome. Simply aiming at putting a floor under the worst possible outcome, this rule ignores the payoffs of more favorable outcomes and does not account for the probabilities imputed to these outcomes (HANF, 1991).

cities, mines or distant plantations are least affected by the fortunes of local agriculture.

FAO identifies “push” factors for the decision of farm-households to engage in rural non-farm businesses. These are among others the absence of crop insurance and consumption credit markets, risks in farming and the failure of farm input markets that compel households to pay for inputs with own cash resources (FAO, 1998).

Flexibility

Flexibility refers to the ability of adapting the original plan to new circumstances. Cropping schemes that allow reallocation of fields to new activities, e.g. after a desert locust invasion will mitigate the adverse effect of the damage. Also wise management of savings and assets maintains flexibility through putting aside resources for times when they are most needed. Savings and asset accumulation are self-insurance measures to compensate the variability in income over time (ANDERSON and DILLON, 1992).

WALKER and JODHA (1986) and WEBB et al. (1992) point out the adverse effects of disinvestment by farmers who sell their productive assets to buy food after poor harvests. This promotes impoverishment by decreasing productivity in the following seasons, which in turn protracts recovery. A certain stock of savings is therefore an important factor in mitigating losses in crop production. The effect of disinvestment should be considered also in the evaluation of desert locust management strategies.

Productivity

Increasing productivity is a key to greater abundance of food and hence has an implicitly risk mitigating effect. It must be noted that this is only true for the long-term trend of the ratio of total output to total inputs, i.e. a system that is “sustainable”. Quite interesting in this context is the fact that ANDERSON and DILLON (1992) explicitly mention the blanket application of insecticides as an example of a strategy enhancing only short-run productivity. The development of resistance in insect and pest populations will render the chemicals useless in the long run. Despite the difficulty of measuring many of those effects that only slowly decrease the resource base (e.g. soil erosion, salinization and loss of benign species[9]), it is important to keep an eye on the

9 For grasshoppers, a recent study found that after chemical control of egg pods the reduction of intact egg pods was higher in the untreated plot than in the treated. This was ascribed to reduced activity of natural enemies in the treated plot. In spite of the fact that this result cannot be

adverse effects that changes in productivity might have. In addition, crop protection can only protect a certain level of output and not enhance production beyond the potential yield. As a consequence, it may be more profitable to enhance the potential output as a first step, e.g. by solving drought or soil erosion problems.

Increased production – especially as a consequence of more intensive input use – increases the value of crops at desert locust risk. A strategy to cope with the desert locust risk might be uneconomic under current production rates but prove economically viable when a higher production value is at stake.

Stability

The concept of stability focuses on the sources of risk and seeks to diminish income variability. An important source of risk in less intensive agricultural systems, particularly in subsistence farming is, of course, production risk.

Yield is the key stochastic variable, whose variability must be controlled by stabilization strategies. The commonly cited example is improving water supply in dryland farming systems in order to decrease dependency on natural precipitation (HARDAKER et al., 1997). The same is true for other production inputs like fertilizers, labor and crop protection. The protection of crops from all kinds of pests is commonly known as an important stabilization strategy. Chemical desert locust control belongs to this category of risk mitigating strategies.

The here presented rather abstract discussion on the ways farmers can manage risks is intended to raise awareness on the coping strategies that are available even for small scale farmers. Evaluators should try to identify the available local adaptation strategies to be able to predict the project effects.

2.2 The framework of cost-benefit analysis

This section introduces cost-benefit analysis as a tool to evaluate public intervention strategies. It provides some background for chapter 4, dealing with the practical application of this tool to the case of desert locust management.

Social cost-benefit analysis (CBA) is a methodology to assess the social impacts of a project or program and is applied to evaluate a wide range of

transferred to the desert locust in general, it can be concluded that benign species may have a notable influence that even exceeds that of chemical control (VALK et al., 1999).

public investments. It provides a framework for systematic assessment of benefits and costs of a proposed investment and gives decision criteria for a rational choice. In the case of desert locust management, alternative strategies can be formulated as independent projects that are evaluated separately. The proposed analytical framework draws mainly on LITTLE and MIRRLEES (1974) and GITTINGER (1982). The project format covers “the whole complex of activities in the undertaking that uses resources to gain benefits” (GITTINGER, 1982) and can, therefore, be applied to a wide variety of investment decisions including those in view of the desert locust problem. It enables the decision-maker to select the efficient project out of a set of available alternative projects.

The project life cycle can be divided into the steps of

- project identification and definition
- identification of costs and benefits
- financial analysis
- economic analysis
- calculation of an investment criterion
- implementation
- evaluation.

However, this outline should not be regarded as a linear but rather an iterative process where the project definition can be changed and improved by using the results of financial and economic analysis. Furthermore, project implementation should be accompanied by recurrent evaluation. A brief review of the steps is given to introduce the basic methodology.

Project identification and definition

As it seems, the first step of identifying possible alternative solutions has suffered from undue negligence in the past. The application of chemical pesticides has been the unquestioned answer to the desert locust problem for a long time until biological methods of pest control became available. Alternative approaches, apart from combating the pest, such as insurance schemes or physical protection are still practically ignored.

Therefore, first of all, a number of conceivable projects dealing with the desert locust problem directly or mitigating the effects in the aftermath of desert locust damage should be identified. Where different project formulations like different definitions of population density thresholds for control are discussed, these should be evaluated, too. See sections 3.1 and

3.2 for remarks with specific reference to desert locust management strategies.

Identification of costs and benefits

Once the project has been defined and its boundaries are identified, the first step is the identification of project costs and benefits. What is incurred as a cost or benefit depends on the objective. Anything that reduces an objective is regarded as a cost and anything contributing to an objective is a benefit (GITTINGER, 1982). Increasing national income is the most important objective of national economic policy especially in developing countries and will apply in most cases.

It must be stressed that the project worth is determined as an incremental net benefit from a with/without comparison and not a before/after approach. The latter would fail to account for changes that would have occurred without the project, like a long-term trend of increasing productivity (GITTINGER, 1982).

Difficulties might arise from the valuation of project benefits and costs when the impacts of the project are not readily predictable. This is particularly a problem with public control and crop insurance strategies. Section 3.3 elaborates on the problem of defining a reference system against which the project impacts can be measured.

Financial analysis

Financial analysis values benefits and costs on the level of a single enterprise using market prices. It aims at identifying the monetary returns to a private individual, a corporation or the government accruing from an investment. It provides information on the profitability and hence the incentives to implement this investment (DIXON et al., 1989; GITTINGER, 1982).

As risk was identified as an important element in farm level decision-making, risk analytical considerations play an important role in the evaluation of profitability and account for a great part of the farm level analysis (section 3.4).

In financial analysis, only the costs incurred by the individual or corporation and the benefits this individual or corporation can acquire, i.e. the monetary returns are considered. External costs and benefits are ignored, because they do not affect profitability of the individual enterprise (DIXON et al., 1989).

Economic analysis

As CBA aims at analyzing the effect of a proposition on social welfare, a broader definition of costs and benefits than that used in financial analysis is adopted. All on-site as well as off-site or external effects of a project must, therefore, be considered in an economic analysis (GITTINGER, 1982). In the desert locust context, this will put up considerable difficulties, because where desert locusts are actively combated, positive externalities accrue to farmers in those areas which were likely to be invaded next by the swarm. To define a clear bio-technological relationship and to measure all physical linkage that cause economic effects is extremely difficult, as is shown by experience and available data (HEROK and KRALL, 1995; JOFFE, 1995, 1998).

In addition, costs and benefits must be measured in efficiency prices that reflect their true scarcity. This means resource utilization must be measured by the opportunity cost, the value of the resource in the second best use (DIXON et al., 1989). Final goods, i.e. those goods that are intended for consumption, cannot be valued by their opportunity cost but must rather be measured by their value in consumption, which is the consumers' willingness to pay (GITTINGER, 1982; MITCHELL and CARSON, 1989). The project analysis proposed by GITTINGER (1982) is valid for small projects only, i.e. those which do not affect output or input markets to a degree that affects the market equilibrium price. Some of the projects discussed in the desert locust context may exceed this "small" project size with regard to the market effects, especially when local markets are poorly integrated and highly variable market supply is to be expected. In this case price changes resulting from shifts in the supply curve must be allowed for in welfare analysis. When the supply of a good decreases, usually its market price will increase. The extent of a price change depends on as many factors as all other product and factor prices, tastes, technology and resource endowments (MISHAN, 1994).

Another difficulty arises, where no markets for a good are available. This is especially true for amenities with public good character, which thus cannot be valued at their market price. A variety of methods have been developed to obtain estimates of the value imputed to these non-marketed goods (HANLEY and SPASH, 1993). See Section 4.2 for details on selected methodologies for non-market valuation.

Also taxes and subsidies must be identified and subtracted, because they represent transfer payments that do not affect social welfare but redistribute resources among members of the society. Interest payments are regarded as transfer payments if they go to a domestic lender, and as costs if they go abroad (DIXON et al., 1989). All costs and benefits are accounted for in the year they actually occur, there is no allowance for depreciation in economic analysis (GITTINGER, 1982).

The interest rate for discounting future costs and benefits should match the social rate of time preference or the opportunity cost of capital (DIXON et al. 1989). The social rate of time preference is difficult to assess. The opportunity cost of capital for most developing countries ranges from 8 to 15 % according to GITTINGER (1982)[10]. If foreign exchange rates are distorted, a shadow exchange rate (SER) must be utilized for internationally traded project inputs and outputs. Ideally, the shadow exchange rate can be obtained from the central planning agency of the respective country. Otherwise it must be calculated from domestic and border prices of traded goods.[11]

Finally, distributional weights might be attached to benefits and costs that accrue to different groups. Due to the involved value judgement it is impossible to give a general recommendation. However, the selection of weights should be in line with the objectives of the project and the selected target groups.

The procedures concerning shadow prices and moving from financial to economic analysis are not presented in this volume, because extensive literature is available (DINWIDDY and TEAL, 1996; GITTINGER, 1982; LITTLE and MIRRLEES, 1974; MISHAN, 1994). Section 3.5 dwells on the methodology of valuing non-marketed goods since these are necessary for the evaluation of many intervention strategies.

Selection and calculation of an investment criterion

For project appraisal, different decision criteria are available that ensure the identification of the efficient set of projects under different conditions. These criteria take into account the temporal dimension of cost and benefit streams by discounting them at an appropriate discount rate. In the following equations, r denotes the interest rate for discounting future benefits and costs. Benefits and costs incurred in year t are represented by B_t and C_t, respectively, while n is the number of years the project exists.

The **net present value (NPV)** is the sum of all discounted benefits and costs of the project and is calculated according to Equation 2.1.

---

10 MISHAN (1988) provides a method to determine the social rate of time preference (pp. 286-293)

11 See GITTINGER (1982, p. 247) for the necessary methodology.

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} \qquad (2.1)$$

The **internal rate of return (IRR)** is the discount rate for which the NPV equals zero. It is the maximum interest that a project could pay to break even. Due to some difficulties associated with this criterion, its use as a single decision criterion is not recommended (MISHAN, 1988, GITTINGER, 1982). For obtaining the IRR iterative procedures must be utilized, which are implemented in standard spreadsheet calculation software.

The benefit cost ratio (BCR) gives the ratio of discounted benefits to the discounted costs of a project:

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}} \qquad (2.2)$$

If projects are independent, i.e. not excluding each other, and there are no constraints on costs, all efficient projects can be selected. Efficient projects are those for which NPV > 0 and BCR > 1, or the IRR exceeds a predetermined discount rate (DIXON et al*.* 1989). When a constraint on the total costs exists, the project with the highest BCR should be selected. In the case of mutually exclusive projects, only the use of the NPV criterion ensures a correct ranking (GITTINGER, 1982).

For an economic evaluation of desert locust management, these criteria should be viewed as *stochastic variables* resulting from the stochastic nature of the benefit and cost streams. With the help of Monte-Carlo-Simulation, it is possible to calculate NPV and BCR distributions if the distributions of benefits and costs are available (MISHAN, 1994; ANDERSON and DILLON, 1992).

Monte-Carlo-Simulation is the most appropriate method in the desert locust context, because risk is a constitutive component of the problem and benefits and costs of the projects in question are subject to highly erratic fluctuations. The tools of formal risk analysis described below can be used to take a decision which is based on the stochastic information and consistent with the decision-makers' risk preferences (see Section 4.4). From the viewpoint of decision analysis, this provides a "better" decision than simply relying on average NPV and sensitivity analysis. Simultaneous deviations of stochastic variables can be accounted for and expectations and risk attitudes are integrated in a formal and understandable way.

Monte-Carlo-Simulation was used e.g. by JOFFE (1998) to obtain the cumulative distribution functions of the NPV of a public control strategy for two different scenarios. These cumulative distribution functions are shown in Figure 2. The detailed methodology is described in Section 4.4.

Implementation

After the most favorable project or set of projects is selected, they can be implemented. Where a thorough accounting of project inputs and outputs and project monitoring accompanies the implementation, recurrent and *ex post* evaluation will be facilitated.

Evaluation

Implementation should not be the last step in the conduct of a project. Rather an evaluation of the project performance should be included. This enables the analyst to discover deviations from the initial plan and to investigate the causes of such deviations. The results of a project evaluation will help to avoid mistakes in the analysis of future projects (GITTINGER, 1982).

Like project identification, *ex post* evaluation of projects has received little attention to date. This is a serious omission, because the experiences of past campaigns could have largely supported improved decision-making for following projects. A draft of guidelines for evaluating control efficacy (MCCULLOCH, unpublished) was developed at FAO several years ago but has never been published. However, it only covers the evaluation of on-site control efficacy. Comprehensive data for this relatively straight forward indicator have not yet been published (JOFFE, 1998). An evaluation of a desert locust control project, however, should go far beyond assessing the on-site effects. Rather the effects of public control operations on crop loss must be assessed, because prevention of crop damage is the overall goal of this strategy. This kind of assessment has not yet been undertaken at all.

For quite some time, negative external effects of chemical pesticide application on the environment have been investigated, among others by the FAO LOCUSTOX project (EVERTS, 1990; EVERTS and BÁ, 1997; LAHR, 1998). However, external effects have not yet been valued and incorporated on the cost side of a comprehensive evaluation study.

2.3 Methods for formal risk analysis

As stated above, the desert locust is an important source of yield risk in the recession and invasion areas. Its migration activity makes damage on the individual farmer's field a stochastic event that cannot be securely predicted. An analytical approach to the desert locust problem should, therefore, include an investigation on the implications of this risk. In this section, a number of methods for risk analysis are presented to provide assistance for further analysis.

As we are dealing with a normative approach to decision analysis, we are concerned with good decisions in the *ex ante* sense of being consistent with expressed beliefs and preferences and not in the *ex post* sense of being free of regret (ANDERSON and DILLON 1992, p. 40). This insight qualifies the practical value of objective probabilities for the individual decision-maker and makes us appreciate the value of subjective probabilities.

Every risky decision problem can be divided into six components:

1. alternative actions (a_I)
2. states of nature (S_j)
3. probabilities measuring the decision-maker's beliefs about the chances of occurrence of the respective states of nature [$P(S_j)$]
4. consequences, outcomes or payoffs (Y_{ij}) of a given combination of alternative action and state of nature
5. the decision-maker's preferences for risky consequences
6. a choice criterion

Considering discrete states of nature, components 1 to 4 can be summarized in the decision matrix representation of a decision problem. In Table 3, the discrete states of nature with their respective probabilities are listed in the rows. The alternative actions form the columns while the outcomes Y_{ij}, often referred to as payoffs, are put into the cells of the matrix.

Table 3: Example of a simple decision matrix

		alternative actions	
state of nature	**probability**	a_1 no insurance	a_2 market insurance
S_1: no locust	1-p	Y_{11}	Y_{21}
S_2: locust invasion	p	Y_{12}	Y_{22}

Source: after HARDAKER et al. (1997)

Modern decision analysis does not anymore distinguish between decision problems where objective probabilities are known and those where they are not, as it was the case formerly. Instead, it is assumed that a decision-maker has at least a vague idea of the probabilities in question. This refers also to cases where the decision-maker is offered a bet on a statement she or he cannot verify at the moment. A decision-maker will be ready to exchange the bet for a lottery with the same payoffs and a probability of success equal to her/his "degree of belief" in a successful outcome of the bet. In this way, the expressed "degrees of belief" can be interpreted as subjective probabilities for the respective outcomes of a decision problem (HARDAKER et al., 1997). These subjective probabilities are relevant for analysis because they apply to the decision-maker's belief about the uncertain setting of the decision, which is essential for a "good" decision[12]. The expected value as a measure of overall performance of a strategy is of great importance and objective probabilities are needed for correct calculation.

So far, only the first four components of a decision problem under risk have been discussed. In the following, a way of incorporating the decision criterion and the preferences of the decision-maker into the analysis are presented.

The concept of expected utility maximization

Supposed the payoffs and probabilities are known, the expected value of the alternative actions can be calculated as the weighted means of their respective payoffs (Equation 2.3). A risk neutral decision-maker will simply select the alternative action with the highest expected value.

[12] The notion of probabilities expressing the degree of belief in a proposition is analyzed in HARDAKER et al. (1997, p. 30) using a reference lottery.

$$E(a_i) = \sum_j p_j Y_{ij} \qquad (2.3)$$

In contrast, a risk averse decision-maker will be ready to forgo a certain amount of money from a risky prospect, if he is offered a sure payoff. It is called the certainty equivalent (CE) of a risky prospect. The CE is a subjective measure that takes into account the risky prospects and hence varies with the degree of risk aversion.

The difference between CE and expected value is called the risk premium (RP) as defined by equation 2.4. It increases with increasing degree of risk aversion. For risk averse decision-makers, an alternative action is preferred if its CE is higher than that of all other alternative actions.

$$E(a_i) - CE(a_i) = RP \qquad (2.4)$$

The CE is a simple measure containing both the matrix components and the preferences of the decision-maker. For every new alternative action the CE must, therefore, be elicited directly from the decision-maker[13].

As an alternative, the concept of subjective expected utility provides the means of expressing attitudes towards risky outcomes in a more universal and versatile way than the certainty equivalent introduced above. Utility theory shows that under a number of axioms[14] an ordinal utility function *u(x)* exists that ranks payoffs according to the preferences of the decision-maker (equation 2.5).

$$u(x_1) > u(x_2) \quad \Leftrightarrow \quad x_1 \succ x_2 \qquad (2.5)$$

Alternative risky prospects can then be ranked by their expected utility. The prospect that maximizes expected utility is the preferred one. When a greater number of alternatives has to be considered, the effort of eliciting a utility function from a decision-maker may be worthwhile. Different elicitation procedures are proposed by HARDAKER et al. (1997), including a detailed discussion of several algebraic representations of utility functions. Alternatively, they provide a descriptive list of ranges for the parameter of constant relative risk aversion *r*, which enables the analyst to choose a relevant parameter value or range for Equation 2.6 which mirrors the risk attitude of the decision-maker.

---

13 A more detailed description can be found in HARDAKER et al. (1997). They also provide methods for elicitation of certainty equivalents or subjective probabilities.

14 The axiomatic foundation of the subjective expected utility hypothesis is presented in ANDERSON et al. (1977).

$$u(x) = \frac{1}{1-r} x^{(1-r)} \qquad (2.6)$$

Utility functions of risk averse decision-makers are characterized by a decreasing marginal utility, i.e. a decreasing slope. By this feature, increasing payoffs yield a relatively decreasing (though absolutely still increasing) utility. As a consequence, the expected value of utilities (equation 2.7) is lower than the utility of the expected value of an uncertain proposition. As the former value is used to calculate the CE from equation 2.8,

$$CE(a_i) = E(a_i)$$

holds true for all risk averse decision-makers (HARDAKER et al., 1997).

Certainty equivalents can easily be calculated from the algebraic representation of the utility function for prospects and its inverse function, denoted by $U(a)$ and $U^{-1}(a)$, respectively, using equations 2.7 and 2.8. It can be seen from the equations, that maximization of CE and expected utility are equivalent.

$$U(a_i) = \sum_j p_j \; u(Y_{ij}) \qquad (2.7)$$

$$CE(a_i) = u^{-1}(u(a_i)) \qquad (2.8)$$

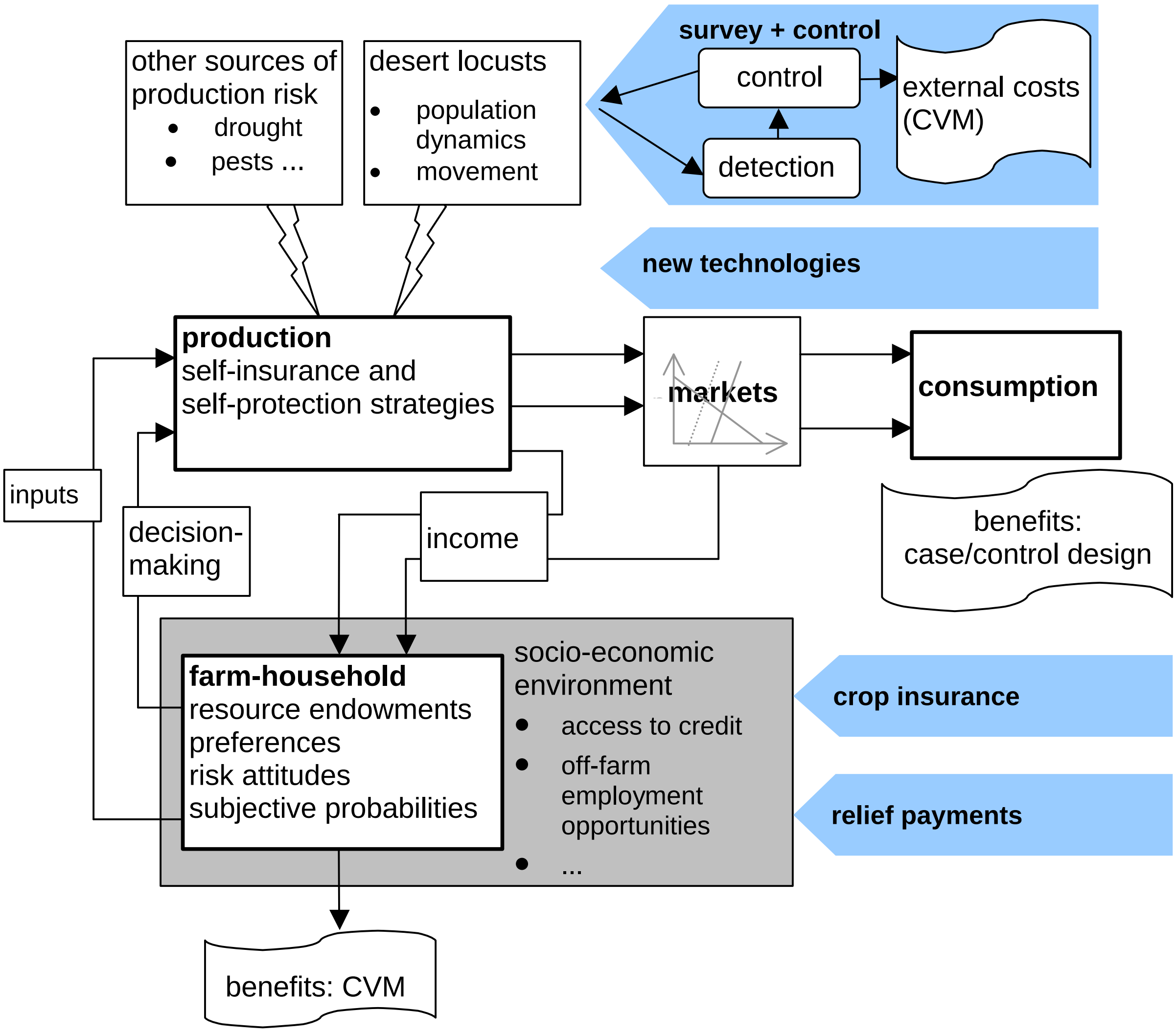
Throughout this text, utility maximization is assumed to be the relevant decision criterion. It is widely accepted as a normative model of choice and it is able to guide the analysis in a wide variety of circumstances (HARDAKER et al., 1997).

The specific examples for farm level analysis presented in section 3.4 will put life into these rather formal and technical descriptions.

3 A new concept of desert locust management economics

So far, the theoretical concepts contributing to an improved understanding of desert locust management economics have been identified. Starting from these considerations, this chapter develops a new concept of desert locust management economics to provide conceptual and methodological guidance for practical studies.

Figure 3: A basic model of desert locust management economics



Source: own presentation

Figure 3 anticipates the new concept graphically. Unlike previous evaluation studies (see Figure 1) this approach moves the farmer into the center. The farm-household is embedded in the socio-economic environment, which among other factors constrains the availability of credit, risk sharing institutions and off-farm employment. The farm-household allocates its disposable resources to on-farm and off-farm production activities to generate income. It decides on the allocation of resources and the farm organization according to its knowledge and preferences, and in particular its risk attitudes and subjective expectations on risky prospects (see section 2.3). As decision-makers are often risk averse, they try to reduce the income variability even if this comes at certain costs. Desert locusts are - just like other calamities in agriculture - a source of uncertainty in production.

The block arrows on the right of Figure 3 represent alternative public intervention strategies influencing different parameters. A strategy of survey and early control aims at reducing the desert locust population, which in turn influences production risk. New technologies can interact with the population dynamics (new control techniques) or with the crop damage potential (mechanical protection, repellents). Economic instruments like insurance and relief payments on the other hand change the socio-economic environment by offering opportunities to mitigate some of the farmer's "business" risks.

All public intervention strategies are understood to take their effects predominantly in an indirect way with farm-household decision-making and farm production as intermediate processes. To be realistic, an economic evaluation of public intervention strategies must be based on farm level data reflecting the results of these processes.

3.1 Specification of objectives

FOCUS: WHY GOVERNMENTS INTERVENE (1)

The literature on desert locust control shows that depending on country specifics and the viewpoints of decision-makers, three objectives play a leading role:

1. The goal of protecting the poor and most vulnerable groups in rural areas refers to the risk of subsistence farmers as well as resource poor producers of market crops losing their living by locally severe desert locust infestations and spillover effects on the rural economy in general (JOFFE, 1995 and 1998; KRALL, 1995)
2. The protection of urban consumers from food insecurities in the form of supply shortages or soaring prices is a related but distinguishable goal (JOFFE, 1995).
3. Protecting valuable export crops is a main reason for intervention especially in the Maghreb countries, where agricultural products like citrus make up an important share of exports (POTTER and SHOWLER, 1991; JOFFE, 1998)

Within and beyond these goals, political reasoning may play a key role in government decisions to engage in desert locust control. As this text is concerned with a framework for economic evaluation the political factors will not be analyzed.

The contribution of public control to specific objectives is not clearly stated in the literature. KRALL (1995), for example, questions that most public control campaigns can protect poor subsistence farmers when they finally fail to prevent locust invasions in their fields. According to his view, the affected farmers are left to their own resort in the end (KRALL, 1995). BENSON and CLAY (1998) suggest that fluctuation in regional income and production due to other causes like drought are much more important than due to desert locust. Other authors cast doubt on the assumption that desert locust control can contribute to food security, because plagues are likely to coincide with exceptionally good regional production as a consequence of humid conditions (BELHAJ, 2000; HEROK and KRALL, 1995).

The first two goals are often cited in favor of donor involvement in desert locust management, although the problem of food insecurity is more complex (WEBB et al., 1992). These authors do not name desert locusts as a main cause for food insecurities and generally distinguish problems of availability of food and access to food. For the case of desert locusts, this is an important insight, because the notion that desert locust plagues are likely to cause widespread and severe losses in agriculture has been severely challenged (BELHAJ, 2000; JOFFE, 1998; HEROK and KRALL, 1995). Provided, food supply is not severely affected, the access to food by affected farmers – especially subsistence producers, who have no means to buy food when their harvests are destroyed - is the more important problem. As a consequence, the scope of public intervention strategies might widen from centering on plant protection towards socio-economic protection approaches.

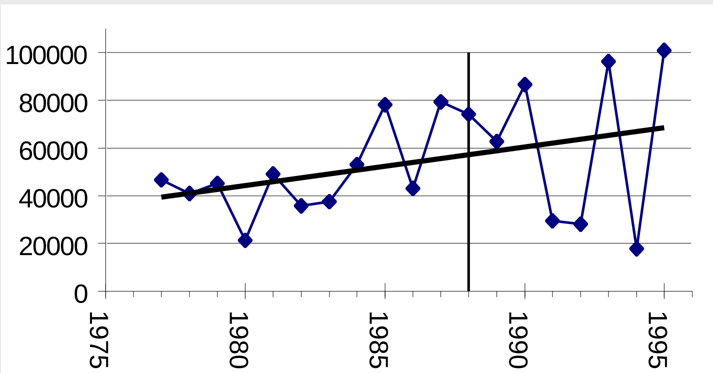
The third argument is a consideration particularly applicable to the Maghreb region, which exports significant amounts of citrus and other fruits, especially to the EU. The dependence on export earnings from agricultural crops may suggest an intervention, but welfare economic analysis should provide the justification for the utilization of public funds.

The first part of the problem analysis dealt with the situation as it presents itself to the project analyst. In a second step, the objectives must be defined to clarify the rationale for intervention and to provide a yardstick for evaluation (FLEISCHER et al., 1999).

Hence, decision-makers should clearly state and prioritize their goals. First of all, **target parameters** like variance of regional food prices, variance of regional farm incomes or the level of productivity in subsistence agriculture etc. should be established. In addition, the **target group** that is intended to receive the benefits from an intervention must be identified to make up a yardstick for measuring the project's success.

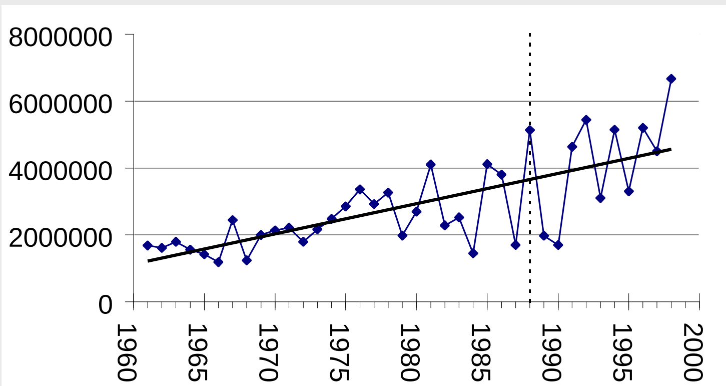
FOCUS: WHY GOVERNMENTS INTERVENE (2)

Figure 4: Cereal production in Morocco (1000 quintal). Plague year 1988.



Source: BELHAJ (2000)

Figure 5: Cereal production in Sudan (MT). Plague year 1988.



Source: BELHAJ (2000)

Figures 4 and 5 depict the cereal production of the recent decades for Morocco and the Sudan, respectively. In both countries, a long-term trend of increasing production is observable while the annual production fluctuates heavily. The plague year 1988 has been marked. The data show production above average in 1988. Either control was very effective in preventing swarms entering both countries or other factors than desert locust damage have a much greater influence on cereal production. Food security in a plague year is at least on the national level not a problem of availability of food. Similar relationships were found by HEROK and KRALL (1995) for Senegal and Mali.

Literature on desert locust management does not provide a clear picture of what is regarded the main target group of public intervention strategies (see Focus Boxes). This is not surprising as a globally defined strategy of public control covers areas with diverse ecological conditions, cropping systems and economic environments. While it is most likely that a single intervention strategy is not simultaneously and equally well suited to tackle the problems of different target groups, it is often overlooked that besides the target group, other groups are affected by intervention measures as well. Hence, these groups have to be identified and their stakes have to be considered in an economic evaluation, too.

3.2 Identification of public intervention strategies

Having established a clear picture of the problem, possible approaches to solve the problem must be developed. This calls for the contribution of experts in different fields including plant protection, economics and sociology working as a team to tackle a common problem.

It is important to consider a broad variety of approaches, including those not related to spray and control, depending on the goals and target groups defined beforehand. In order to give an idea of conceivable intervention strategies, four ways of approaching the problem from a socio-economic, technical and a crop protection viewpoint will be discussed in short.

3.2.1 Crop insurance schemes

FOCUS: FAILURE AND SUCCESS OF CROP INSURANCE

Multiple peril crop insurance was offered by state-run insurance schemes in several countries. While only relatively few farmers bought this insurance, subsidy shares ranged from 25% in the USA to 50% and 80% in Brazil and Mexico, respectively (HAZELL et al., 1986a). Analyzing the US federal insurance program, the too broad coverage of perils, insufficient data for actuarial appraisal and contracts written late in the season were identified as the main reasons for failure of multiple peril insurance (GARDNER and KRAMER, 1986).

On the other hand, a mandatory all-risk insurance for cotton growers in Brazil operated with an average loss ratio (indemnities divided by collected premiums) of 0.96 over 17 years and was judged successful (REZENDE-LOPEZ and SILVA DIAS, 1986)

HAZELL et al. (1986a), recommend crop insurance for those cases where yield risks are the main source of income fluctuations, especially where a risk of catastrophic outcomes exists. The success of commercial insurances for hail and fire indicates that risks from natural disasters can be insured (SIAMWALLA and VALDÉS, 1986; SKEES et al., 1999).

Based on historical evidence, KRALL (1995) states that the current public control strategy cannot prevent crop losses completely or even satisfactorily from an economic point of view. The individual farmer is left to her or his own resort once damage is inflicted on the fields. That is why crop insurance on the analogy of hail insurance in many developed countries is considered an at least theoretically very appealing option (KRALL, 1995). Informal arrangements within tenancy contracts or extended family networks are often the only way for sharing the risk of agricultural production in many developing countries (SIAMWALLA and VALDÉS, 1986). They will fail, however, when regionally and temporally concentrated disasters strike (HAZELL et al., 1986). Desert locust damage due to the movement of swarms is such a locally and temporally concentrated disaster. Desert locust risk may therefore be difficult to cover within informal security networks. Against this backdrop, market insurance is an attractive complement to the available informal arrangements.

FOCUS: MORAL HAZARD

Moral hazard is a phenomenon that occurs because of asymmetric information and incompatible incentives. Once an individual is insured against a risk, the incentive to self-protect is canceled and the insured might increase the exposure to risk. Asymmetric information denotes the inability of the insurer to observe the change in the insured's behavior. As an example, health insurance is frequently cited: with insurance, the individual has less incentive to produce an effort to maintain its health. Moral hazard discourages the individual effort of preventing insured losses decreases (NELSON and LOEHMAN, 1987).

However, crop insurance has never been seriously considered as an alternative. Critics of an insurance scheme point to the inadequate performance of crop insurances in many developed countries (see Focus Box). However, high subsidy shares were predominant in multiple peril insurances, only. Hail or fire insurances are generally offered by private enterprises in competitive markets. Table 4 gives an overview of some important properties of different sources of risk and shows that the desert locust and hail perils correspond with respect to all of the listed properties. Most importantly, the extent of information asymmetry with these risks is significantly lower than with multiple peril insurance. Asymmetric information refers to the inability of the insurer to observe the insured's behavior and becomes a problem when the latter slackens self-protection efforts because she or he is insured. While this increases the exposure to risk, the insurer cannot observe this behavior and adjust the actuarial premium accordingly, which leads to moral hazard and adverse selection (see Focus Boxes). Natural disasters like hail or desert locust damage occur randomly and can not be influenced by the single farmer, except for changing the timing of planting and harvesting. But this behavior and the cause of a damage are observable to the insurance provider. Hence, moral hazard and adverse selection can be expected to play a minor role in hail and desert locust insurance. Furthermore, providing only partial coverage for the insured damage can reduce these problems (SKEES et al. 1999).

Table 4: Analogy of different crop insurance schemes

Indicators	Type of insurance		
	hail	**desert locust**	**multiple peril**
severity of damage	high	high	medium to high
probability of damage	very low	very low	medium
influence of the insured on damage probability	low	low	significant to high
asymmetric information	low	low	high

Source: own presentation

Furthermore, one might argue that the insufficient institutional infrastructure in many developing countries would render insurance infeasible or extremely costly. Different arrangements have been proposed to deal with this problem. For a reduction of administration costs, the cooperation with rural development projects, cross-training of existing insurance staff (e.g. from livestock insurance) or recruitment of part-time agents and village personnel for the field operations have been suggested (GUDGER and AVALOS, 1986). However, the standard insurance scheme of individual contracting and indemnity claims could be left behind. This would offer another way of reducing the costs and coping with an insufficient infrastructure. Insurance policies could be sold at post offices or stores like lottery tickets. The indemnities could be claimed at the same institutions after an announcement in the media that the insured event has occurred. This arrangement offers insurance also to other groups that depend on agricultural crops like rural processing enterprises or farm laborers. These groups would not be eligible for

FOCUS: ADVERSE SELECTION

Adverse selection occurs, when an insurer cannot judge the risk of an individual farmer. Usually, the insurer can obtain information on the risk of only a group of farmers. The insurance company fixes the premium in accordance with overall expected value of indemnities. For farmers whose expected loss (plus risk premium) exceeds the insurance premium, insurance is attractive. They will buy the insurance contract. Farmers, who expect lower losses on average, will refrain from buying the insurance contract because insurance is unattractive. As a consequence, “good” risks leave the insurance while “bad” risks remain. This results in an increase of average losses and increasing premiums (HAZELL et al., 1986).

a traditional crop insurance scheme but suffer similar to farmers from crop failures. In a discussion paper, SKEES et al. (1999) explore the advantages and constraints of an index-based insurance scheme for rainfall which bears some similarities with desert locust damage insurance. They give useful guidance for the development of viable and inexpensive insurance schemes. Moreover, the utilization of different ways for risk diversification and reinsurance including internationally traded catastrophe bonds and World Bank contingency loans as cheaper alternative to traditional reinsurance are suggested. They conclude that insurance along these guidelines need not to be costly to the government and can still be attractive to the individuals facing the risk (SKEES et al., 1999).

It is obvious that depending on the specific country circumstances, a suitable scheme will have to be developed according to the specific risk, the economic and social infrastructure and the targeted farmer groups.

Table 5: Pros and cons of desert locust insurance

Pros	Cons
• farmers benefit from reduced income variation • preservation of productive capacity, stabilization of consumption • farmers can reduce costly self-insurance efforts • reduced spillover effects (labor market, credit market) • financial self-sustainability can be attained	• physical damage is not prevented • considerable transaction costs, especially when infrastructure is weak

Source: own presentation

Table 5 summarizes the arguments for and against desert locust insurance. Most of the pros refer to the benefits crop insurance can give to various stakeholders. The assessment of some of these benefits is discussed in the proposed farm level analysis in section 3.4. By charging the beneficiaries for the costs of insurance, this intervention strategy can develop into a financially self-sustainable institution after an initial phase of subsidization (see also SKEES et al., 1999). Insurance does not actually prevent physical damage. However, this does not *ipso facto* render insurance an uneconomical option when the damage potential is high and widespread. Depending on the risk perceptions of the affected farmers and the transaction costs for implementing the insurance, the insurance solution may still tally up with alternatives. Section 3.3 will explain how the optimal intervention strategy is determined by the comparison of net benefits of alternative strategies.

3.2.2 Public relief disbursement after localized severe damage

The effects of an institutionalized relief system are similar to those of insurance, since the income risk is mitigated. Transaction costs can be expected to be lower than for insurance schemes, because no signing of insurance contracts and monitoring of indemnity claims are necessary. On the other hand, the beneficiaries do not contribute to covering the costs, which results in a substantial income transfer from the taxpayer or donors to the recipients of relief. In addition, relief schemes are exposed to political bargaining and the disbursement of funds may be contingent on the prevailing budget constraints (see also the Focus Box). Table 6 summarizes the pros and cons of relief payments.

Table 6: Pros and cons of public relief disbursement for desert locust damage

Pros	Cons
• preservation of productive capacity, stabilization of consumption • farmers may reduce costly self-insurance efforts • reduced spillover effects (labor market, credit market)	• physical damage is not prevented • financially not sustainable • disbursement subject to political decisions • (income transfer) • targeting may be difficult

Source: own presentation

As it is generally undesirable to cover the risks of individual enterprises with public funds, a relief arrangement is an interesting proposition only if the target group is small and well-defined and it is unquestionable that the group cannot significantly contribute to the costs of insurance. This has to be considered especially when relief is introduced as a parallel intervention with market insurance. The latter would be unattractive once relief payments can be expected for sure. But for protecting subsistence and resource poor farmers from malnutrition and prolonged impoverishment and to prevent the forced

FOCUS: EXPERIENCE FROM DROUGHT RELIEF

For relief schemes, the beneficiaries do not contribute to financing the costs. Such a program will always remain costly to the government or donors. It will also be contingent on the political environment and budgetary constraints. BENSON and CLAY (1998) criticize the related unsustainable welfare dependence of vulnerable areas and groups in the case of drought relief. In addition, a tendency to influence public crop insurers for political goals has been frequently observed. GUDGER and AVALOS (1986) mention Costa Rica as an example. Public relief measures are prone to misuse for political goals, since they are often invoked on emergencies without a highly formalized decision process. They further report a tendency of Australian and South African farmers to refrain from buying drought insurance, because relief can be expected with high likelihood once a severe drought occurs.

A third point is the form of payment. Results of studies on the economic impact of drought in Sub-Saharan Africa reveal that food for work programs are not necessarily the best option. Instead, in more complex economic systems, cash for work, food coupons or other cash transfer mechanisms may prove more efficient. Post-disaster recovery support like the provision of seeds and the rehabilitation of livestock, which is in principle regarded a prerequisite for a quick recovery and the prevention of prolonged impoverishment, has generally been handled poorly (BENSON and CLAY, 1998).

depletion of their productive assets for food, well-implemented relief schemes can improve the well-being of the rural community.

As this project demands for considerable contingency funds from donors or governments, which might itself increase risk, because they are dependent on political decisions. In addition, many governments may not have the liquid assets in the event of a catastrophic loss (GUDGER and AVALOS, 1986). This of course would completely counteract the objectives.

The mentioned drawbacks exclude this strategy as a general approach, because it gives rise to incompatible incentives that reduce efficiency. As a consequence, it is only a proposition for the protection of a small, focused target group that otherwise incurs an immediate threat to livelihood.

The payment of relief in whatever form may be a necessary intervention when the most vulnerable incur severe losses and other strategies prove either too expensive or ineffective in protecting them. It is, however, an intervention that is costly in the sense that beneficiaries do not contribute to its financing. Nevertheless, targeted relief measures might help to maintain the productive capacity of the farm-household. This potential should be explored thoroughly.

If the relief is not properly targeted, the incompatible incentives induced by an assurance of relief payments would counteract more efficient coping strategies by making farmers externalize their risks. As a consequence, this proposal is rather suitable to be implemented along with other interventions applying to a broader target group. In such cases, it is a complementary part that safeguards the poor.

3.2.3 Continuation of control

The continuation of public engagement in control measures is, of course, one of the alternatives to be considered. As most readers will be familiar with this strategy, only a short summary of the pros and cons is presented in Table 7.

Table 7: Pros and cons of continuing public control

Pros	Cons
• prevention of physical damage • reduction of yield variation	• economic performance questionable • financial self-sustainability improbable • production losses (livestock, bees) • health and environmental costs

Source: own presentation

Concerning the benefits, it must be stressed that a clear cause and effect relationship between the extent of preventive control in remote areas and yield losses prevented has not been scientifically established, yet. The cons listed in Table 7 refer on the one hand to the economic performance and to the project's capability of acquiring the costs from the beneficiaries. On the other hand, external costs of pesticide application are listed, which have yet to be included in the economic evaluation.

3.2.4 New technologies

Improvements in the management strategy and the use of forecasting and simulation models could contribute to reducing the internal and external cost components or to improving the impact of control interventions. In addition, the use of biological agents and other innovative technical solutions for an approach based on the principles of integrated pest management (IPM) could be compared to other alternative management options.

Concluding remarks

The intervention strategy should be clearly stated to facilitate the process of identifying costs and benefits in an *ex ante* evaluation. Similarly, implementation of the investment and monitoring of achievements will benefit from a clear formulation.

It is improbable that one strategy proves to be the optimal one for all affected countries. Even within a country, where different agro-ecological zones prevail or different project goals are pursued, the optimal strategies might differ. As a consequence, also a combination of strategies – e.g. prevention and mitigation of losses from desert locusts - may prove the economically optimal choice.

If external effects beyond the project area are to be expected (e.g. externalities of desert locust control), these have to be considered for the decision, too. While it is straightforward to account for these effects on a national level (once a weighting function has been identified), the task gets difficult if several independent national economies are involved. A game-theoretic model is presented in section 3.7 to explain the decision situation and to derive a rule for determining the amount and direction of side payments.

3.3 Identification of a reference system and definition of loss

To compare different strategies, the definition of a reference system against which improvements are measured is a prerequisite. GITTINGER (1982) emphasizes that the project worth is measured by comparing the situation "with the project" and the situation "without". This seems trivial but there is a difference compared to measuring the project value following a before/after approach. The latter could not differentiate long-term trends from changes that have been brought forward by the project itself. This is why a case/control design is recommended for the analysis.

A second important point is – especially in the field of plant protection – the identification of a relevant definition of loss. The term yield loss bears negative connotations and has been used in various meanings (ZADOKS and SCHEIN, 1979). For the purpose of decision-making in plant protection, economic loss is more important than any measure of physical yield loss. The following paragraphs explain the term economic loss and show how it is determined by utilizing the risk analytical tools introduced in section 2.3[15].

---

15 For an alternative definition see also Appendix A-4.

According to WAIBEL (1990), loss refers always to the difference between outcomes when an action is either taken or not. This concept can be captured most conveniently in a decision matrix. The strategies “action” and “no action” are alternatives presented in the columns, while outcomes are the cells of the table. The states of nature, i.e. the possible pest situations are entered in the rows (see Table 8). The decision on what strategy to pursue has to be made before the state of nature is known. In the case of the desert locust problem, there are two possible situations in which losses occur:

a) No control is undertaken but a locust plague destroys part of the crops in the country. National income is reduced by the lost production of agricultural commodities.

b) A public control strategy is in effect, but locusts are in a recession period and do not threaten the harvests. The expenditures for survey and control measures in remote areas are lost.

For further exploration, see the exemplary decision matrix presented in Table 8. Note that all values given in the matrix are hypothetical. The probability of a desert locust plague is slightly overestimated since history has shown that on average one of every six years is a plague year (JOFFE, 1995). The other values denote national agricultural income. It is assumed that without locusts, the national income is 500 million in arbitrary units. In a plague year, agricultural production destroyed by locusts amounts to 20 percent or 100 million units of national income if left uncontrolled. When neither farmers nor the government intervene, only 400 million units remain as a national income from agriculture. Further it is assumed that public monitoring and control campaigns cost 10 million units every year. Then, given a control strategy is chosen, the agricultural sector has a net production of 490 million units in a recession year. When a plague occurs, a residual damage of 4 percent remains. Equivalently, it could be assumed that only a residual damage of 2 percent occurs, but control costs are increased under plague conditions.

Table 8: Decision matrix for a public decision-maker[16]

		Alternative actions	
State of nature	**Probability**	a_1 public control	a_2 no control at all
s_1: recession year	0.8	490 million	500 million
s_2: locust plague year	0.2	488 million	400 million
Expected value[17]		489.6 million	480 million

The hypothetical payoffs represent national income from agriculture in arbitrary units.

Source: own presentation.

The different types of loss shall now be explored with respect to the hypothetical example in Table 9. The *potential loss*, is the difference between the most favorable outcome (a_2/s_1) and the worst outcome (a_2/s_2) (WAIBEL, 1990) and amounts to 100 million units in the example. This definition of loss is used to point out the economic dimension of the desert locust problem. See for example the figures cited by KRALL (1997, p. 405 and 1994, p. 9), STEEDMAN (1990) and JOFFE (1995, p. 27). However, this type of loss may not be interpreted as the economic loss, as will be shown below.

The type of loss described under (a) corresponds to the regret that is felt when the strategy of "no control" was decided on and public control has proven the better alternative, since the state of nature turned out to be a plague year. In our example this is 88 million units, the difference between 488 and 400 million units of agricultural income. Note that this loss is not the same as the potential loss of 100 million units in this example. The costs of the public control strategy and its incomplete abatement success account for the difference.

The type of loss described under (b) above corresponds to the regret when public control is undertaken and it turns out that there is no real threat of locusts. It is the difference in payoffs between (a_1/s_1)and (a_2/s_1). Then the costs of public control amounting to 10 million units are incurred as a loss.

However, the loss of type (b) has rarely been termed "loss" and instead been called costs. Of course, technically, there is no difference. Yet the term loss

16 The fact that public control compares favorably in the hypothetical example is not to be interpreted as a prejudice of the author.

17 The expected value is calculated as the sum of the payoffs weighted with their respective probability. For a_1, the expected value is computed as follows:

0.8 * 490 million + 0.2 * 488 million = 489.6 million.

bears a negative connotation and it may be misleading to distinguish the two types of loss.

The definition of economic loss integrates these two types of loss: *economic loss* is the difference between *net returns* for the control strategy and the "no control" strategy weighted with the probabilities for the plague and recession scenario, respectively (WAIBEL, 1990). In other words, economic loss is the difference between the expected values of income. It amounts to 9.6 million units in the example of Table 8.

Conclusion 1:

> Economic loss is defined as the difference in expected values of net returns of two alternative abatement strategies. It should not be confused with the potential loss, which is always higher. Potential loss can be used to demonstrate the scale of a pest problem but may not be used to judge the efficiency of strategies. Instead, in an economic sense strategies have to be compared to one another. A loss only occurs, if a strategy is chosen which is less efficient than the optimal one. To obtain the optimal solution, all possible technically efficient strategies must be compared. Strategies are not compared with respect to the resulting yield loss. Instead, the *net returns* are the target parameter, because they include the benefits as well as the costs of each abatement strategy.

There is still another problem: the above discussion applies to plant protection decisions on farm level, which is appropriate for many pests. Desert locust control has been regarded as a public task, however, so that public authorities take the decision. This would also be covered in the above example. However, in a market economy decisions are decentralized and take place on the level of the individual consumer or enterprise. Hence, farmers will adapt to maximize their expected utility[18] under the actual policy framework. As a consequence, there is no scenario "without control" in reality, because farmers will choose strategies to mitigate the risk of severe losses. Farmers could adopt mitigation and coping strategies e.g. keep stocks, replant upon a desert locust damage. Table 9 takes account of farmers' reactions to a "no public control" scenario.

---

[18] The simple assumption of profit maximization would neglect the impact of risk, so that the concept of expected utility maximization is more suitable. However, the objectives of a farmer may be even more complex.

Table 9: Decision matrix for a public decision-maker allowing for farmers' adaptation

		Alternative actions	
State of nature	Probability	a_1 public control	a_2 no public control but farmers' coping strategies
S_1: recession year	0.8	490 million	490 million
S_2: locust plague year	0.2	488 million	460 million
Expected value		489.6 million	484 million

The hypothetical payoffs represent national income from agriculture in arbitrary units.

Source: Own presentation

If it is further assumed that the coping strategies of farmers come at the total cost of 10 million units. There is no difference in recession years. In the example, the residual loss of farmers' coping strategies is assumed to be higher than that of public control. In a plague year, agricultural income falls to 460 million units. In the example, public control has still the highest expected value. But taking into account farmers' coping strategies, economic loss is reduced to 5.6 million units and is considerably lower than the loss calculated without accounting for farmers' reactions.

Conclusion 2:

> Provided that farmers can employ coping strategies, any analysis of public strategies must take the effects of farmers' reactions into account. Especially for important risks, the affected farmers will try to insure or protect themselves. This will reduce the difference between the welfare effects of the "pure" public intervention strategies.

As a consequence, the decision on locust damage abatement strategies must be understood as a two-stage process. First, the public control policy is selected. Then, the farmer adapts to the desert locust threat as she or he perceives it under the given control policy. This fact, however, has not been observed in economic evaluation of public control to date and may have caused an overestimation of the benefits of public control. The proposed framework for evaluation of public investment in desert locust management presented here will account for farmers' choices by eliciting data on the farm level.

A third issue remains to be discussed: Up to now, the considered strategies for public intervention were limited to two options: control and inaction. The introduced framework intends to broaden the scope of intervention strategies, to be considered including insurance schemes and new technologies for protection. The decision matrix is extended to account for a alternative strategies (Table 10). It is assumed for simplicity that offering insurance and a public control strategy are excluding alternatives. Hence, under the insurance strategy, the desert locusts are assumed to cause the same damage of 40 million units. But in recession and plague years, the insurance offers an alternative way of risk bearing to farmers and reduces their costly self-insurance measures, finally resulting in higher efficiency as denoted by the payoffs. The costs of running the insurance occur in both states of nature and are included in the assumed payoffs.

In Table 10, the insurance strategy yields an expected national income comparable to that of public control intervention, because it is less costly than control in recession years and reduces inefficiencies in plague years. The cost of refraining from public control interventions is now no longer the difference between strategies (a_1) and (a_2) but between best (a_1) and second best (a_3) strategy. This difference amounts to only 0.6 million units in the example. It is significantly lower compared to the previous example where only public inaction was considered as an alternative.

Table 10: Decision matrix for a public decision-maker considering several strategies

		Alternative actions		
State of nature	**Probability**	a_1 public control	a_2 no public control	a_3 insurance
S_1: recession year	0.8	490 million	490 million	495 million
S_2: locust plague year	0.2	488 million	460 million	465 million
Expected value		489.6 million	484 million	489 million

The hypothetical payoffs represent national income from agriculture in arbitrary units.
Source: own presentation

Conclusion 3:

> The cost of refraining from the optimal strategy is the difference between the expected values of the optimal and the second best strategy. For identifying the economically optimal management option, technical alternatives should be explored. The comparison of alternative strategies can be accomplished by using the summary criteria of a cost-benefit analysis as long as the analysis evaluates each strategy against a common reference scenario.

In this context, it is proposed to define *a scenario of no public intervention but with farmers' adaptation* as a reference system. Alternative strategies can be evaluated according to their incremental income generating performance against this reference situation. It is obvious that the evaluation of intervention strategies has to consider farmer adaptation to the changed desert locust threat as well in order to give a true picture of real behavior. As a consequence, farm level data have to be utilized for the evaluation of desert locust management strategies.

3.4 Components of farm level analysis

The previous chapter emphasized the importance of farm level decisions. Following the procedure of cost-benefit analysis presented in section 2.2, this section will provide the basis for financial analysis, i.e. the evaluation of profitability on the level of individual enterprises. As a first step, alternative approaches to cope with and mitigate the risks associated with desert locusts will be discussed. Then, farmers' reactions to the desert locust risk are explored using decision matrices. It will be shown that different policy outcomes will be modulated by farmers' reactions.

The choice of an optimal risk management strategy

SCHULENBURG (1992) recommends different management strategies for different kinds of risk (Table 11). When both, the probability and severity of damage are high, risk avoidance is the recommended strategy. In the opposite case, when probability and severity of losses are concurrently low, it is straightforward that the risk can be borne easily. Less trivial conclusions are drawn for the cases when either probability or damage are high.

If the probability of a moderate or low damage is high, the best strategy will be *self-protection,* which aims at preventing the damage. This effectively means a reduction of the probability of the adverse state of nature. With this strategy, however, once losses have occurred, their adverse impact is not mitigated. A strategy of self-protection comes at the cost of prevention measures and results in a reduced income in both, adverse and favorable states of nature. The income variance is not necessarily reduced but the mean or expected value of the income distribution is increased (SCHULENBURG, 1992).

This strategy does not seem to be a sensible approach to the desert locust problem, because it does not solve the problem of high potential damage. It still leaves the farmer at risk of his livelihood. The current control strategy falls into this category. Until now, it has failed to completely protect farmers from damage, although it might have reduced the frequency of calamities. However, no provision is made for the case that the desert locust invasion reaches the individual farmer's field. She or he is still left to her/his own resort. Such a strategy eventually fails to protect vulnerable groups from threats to their livelihoods.

When the potential damage is high but the probability of occurrence is low, self-insurance or market insurance are recommended. Insurance in general is the act of redistribution of income towards less favorable states of nature (EHRLICH and BECKER, 1972). For the desert locust risk, self-insurance comprises on-farm measures that diminish income in favorable states (i.e. years without locust damage). It provides funds during less favorable states of nature. The application of protective nets for example causes costs in all years (reducing expected net returns) but will prevent losses when locusts invade the crop.

The profit of self-insurance depends among others on the probability of damage. In most cases the costs of mitigation measures are independent of the probability distribution, whereas the benefits of self-insurance are not. The latter depend on how frequently damage will occur and on the extent of mitigation. On the contrary, demand for market insurance is independent from damage probability. Any change in probability equally affects benefits as well as costs, since the premium is fixed by the insurance company to match expected indemnities plus administration costs. The effect of insurance activities on the distribution of income is generally a reduction in variance (EHRLICH and BECKER, 1972).

Table 11: Optimal risk management measures

		Severity of damage	
		low	**high**
Damage probability	**low**	• take the risk	• insurance • self-insurance (damage mitigation)
	high	• self-protection (damage prevention)	• transfer the risk • reject the risk

Source: after SCHULENBURG (1992)

From the farmer's viewpoint, the event of desert locust invasion is very rare, while the severity of losses might be very high. Thus insurance is the apt strategy, because it will mitigate the impact of the adverse state of nature. Market insurance and self-insurance are substitutes, i.e. they can replace each other and are selected according to their respective costs (EHRLICH and BECKER, 1972).

The available risk management strategies vary largely with the cropping system, the resources the farmer controls (labor, cash availability, knowledge etc.) and the economic system (input and output markets, insurance and rural finance markets etc.). As JOFFE (1998) has shown, producers of export crops will bear a great share of the economic burden of a desert locust damage, because the losses will be too small to cause a rise of world market prices. On contrary, farmers producing for local or regional food markets will encounter a price rise when regional production is reduced by a large-scale desert locust damage. Farmers who manage to have crops left for sale, will get higher prices. In this case, the farming sector is partly compensated for the losses, while the consumers loose through higher prices. Subsistence farmers will bear the full burden of losses, since both, their production and consumption are affected and no substantial cash is available to purchase foodstuff.

For these reasons, it is difficult to propose coping and mitigation strategies that are applicable to the whole area affected by desert locusts. Instead, an example is used to highlight the farmer's decision.

The farmer's decision

In order to analyze the farmer's decision, let us assume that the farmer distinguishes two different states of nature, S_1: no locust invasion and S_2: locust invasion. Suppose that she or he has the choice between three different strategies concerning the desert locust problem:

(a_1) no insurance

This strategy corresponds to a cropping scheme that yields maximum income in "good" years but is at the same time prone to desert locust damage. In the case that no locusts appear, her/his income will be Y_0, otherwise it will be reduced by the amount of the losses L_1.

(a_2) market insurance

The intense cropping scheme of the above alternative is implemented but additionally insurance is bought at the premium C_2 which fully compensates losses from desert locust damage. The farmer's income will then be Y_0 minus the premium C_2, independent of the locust situation.

(a_3) self-insurance

In this strategy, an on-farm coping strategy is applied, e.g. income diversification or the use of protective nets on fruit trees. The farmer's income will then be reduced by the costs of this strategy C_3. In the case of desert locust invasion a residual damage will reduce his income further by L_3.

In principle, the decision problem, formally represented in Table 12, is applicable to many farmers' situations in desert locust prone areas. Depending on cropping schemes and available strategies, the numbers to be assigned to the payoff variables will vary. Note, that it is not necessary to express any of the variables in monetary terms. The scheme will work equally well if all values are expressed in kind, e.g. cereal production.

Table 12: Decision matrix for a farmer (without self-protection)

		alternative actions		
state of nature	**probability**	a_1 no insurance	a_2 market insurance	a_3 self-insurance
S_1: no locust	$1\text{-}p_1$	Y_0	$Y_0 – C_2$	$Y_0 – C_3$
S_2: locust invasion	p_1	$Y_0 – L_1$	$Y_0 – C_2$	$Y_0 – C_3 – L_3$
E		E_1	$E_2 = Y_0 – C_2$	E_3
CE		CE_1	$CE_2 = Y_0 – C_2$	CE_3

Source: own presentation

Choice criterion and a definition of loss

Contrary to the public decision-maker in section 3.3, who was assumed to be risk neutral, farmers are expected to be risk averse in general (ANDERSON and DILLON, 1992; BINSWANGER, 1980; HARDAKER et al., 1997). According to utility theory (see also section 2.3) risk averse decision-makers maximize expected utility – or the certainty equivalent. Hence, the strategy with the highest certainty equivalent (CE) is preferred by the farmer. If the farmer would choose another strategy, he would perceive a loss that amounts to the difference between the CE of the best and the selected strategy. For a risk averse farmer, the CE of an uncertain prospect is always lower than its expected value. Note that economic (social) loss is not the difference in CEs but in expected values (E) of best and implemented strategy (WAIBEL, 1990).

Hence, in an economic sense, there is no loss through desert locust as such, because this phenomenon must be taken as a natural constraint to economic activities. A complete eradication of desert locusts is neither technically feasible today nor necessarily desired. Therefore, there is no question of “with” or “without” locusts. *Economic analysis*, therefore, concentrates on the *selection of strategies efficient to cope with the desert locust problem*. It is then straightforward that losses only result from the implementation of less efficient strategies when better ones are available or could be provided.

Example 1

For transparency reasons, an example is constructed with hypothetical values assigned to the variables. Due to the lack of data, these values have not been drawn from an empirical study nor is it claimed that they apply to certain real cases.

The following values are assigned to the variables in Table 12. They are given in domestic currency units (DCU) or in crop equivalents:

Variable	DCU	
Y_0	500	income without the locust event if strategy (a_1) is chosen
L_1	450	income loss through locusts (assumed to be 90% of maximum income)
C_2	60	costs of insurance = premium
		The premium is fixed by the insurance provider to meet the expected expenditures for refunds (here DCU 45 as a 10 year average of damage) plus transaction costs (DCU 15).
C_3	50	costs of self-insurance strategy (10% of maximum income)
L_3	100	residual loss

Under the assumption that the farmer shares the expectations of the insurance company that a loss of DCU 450 occurs every 10 years on average, Table 13 gives the decision matrix. The calculation of the expected monetary values (E) according to equation 2.4 is straightforward. For an analysis of the farmer's decision, certainty equivalents for the alternatives are calculated, which incorporate the farmer's risk attitude. For this purpose, it is assumed, that the farmer's utility function can be described by equation 2.6. Furthermore, the parameter r of the function is set to 2. Choosing this value for the coefficient of relative risk aversion mirrors "rather risk averse" behavior according to HARDAKER et al. (1997, p. 102) and ANDERSON and DILLON (1992). It seems appropriate to assume a degree of risk aversion higher than "normal", because especially poor farmers face an immediate threat to their livelihoods if severe losses occur[19]. As we are dealing with losses, even higher values could be

[19] "Normal" risk aversion corresponds to a coefficient of relative risk aversion of 1. The results presented here only change when the coefficient is chosen to lie below 1.1. BINSWANGER (1980) found the majority of rice farmers in an Indian village to exhibit coefficients of relative risk aversion

justified, following the argument of KAHNEMAN and TVERSKY (1979), that decision-makers are even more loss averse than risk averse.

To make the steps of obtaining the certainty equivalent (CE) more transparent, the calculation is presented in detail for the first alternative action a_1 (see Table 13). Using $r=2$, we obtain from equation 2.6 (p. 30)

$$u(x) = \frac{1}{1-2} x^{(1-2)} \quad = -\frac{1}{2x}$$

as the farmer's utility function. With this function, the utility of each of the payoffs is computed separately:

$$u(500) = -\frac{1}{2*500} = -.001 \quad \text{and} \quad u(50) = -\frac{1}{2*50} = -.01$$

Next, the expected utility of the first alternative action u(a1) is calculated as the weighted average (equation 2.7, p. 30) of the utility of each payoff with respect to the imputed probabilities:

$$u(a_1) = p_1 * u(500) + p_2 * u(50) = .9*(-.001) + .1*(-0.01) = -.0019$$

To transform the abstract utility estimate back to a monetary value, i.e. the certainty equivalent of a_1, the inverse of the utility function is used. In this case, it happens to be of the same functional form as the original utility function:

$$u^{-1}(x) = -\frac{1}{2x} \qquad u^{-1}(u(a_1)) = CE(a_1) = -\frac{1}{2*(-.0019)} \approx \underline{\underline{263.1}}$$

All other CEs in the following examples are calculated in the same way by using the same utility function.

in the range of 0.32 to 1.74, while still 16% of respondents had a 1.74 < r > 7.5. ANDERSON and DILLON (1992, p.75) suggest r = 4 for farmers with very low-income.

Table 13: Sample decision matrix

		alternative actions		
state of nature	**probability**	a_1 no insurance	a_2 market insurance	a_3 self-insurance
S_1: no locust	**0.9**	500	440	450
S_2: locust invasion	**0.1**	50	440	350
E		455.0	440.0	440.0
CE[20]		**263.1**	***440.0***	**437.5**

Source: own presentation

When the farmer chooses not to insure, she/he earns a maximum income of DCU 500 in locust free years. When locusts invade her/his fields, only 10% of his usual income remains. On average, the farmer expects an income of DCU 455 with this strategy. The CE of this strategy is much lower than the expected value – as a consequence of the high variability of income and the high risk aversion (Table 13). Buying market insurance that fully covers the losses due to desert locusts at a premium of DCU 60 levels the income to DCU 440 irrespective of desert locust damage. This sure payoff ties up with the CE. Self-insurance comes at the cost of DCU 50 in any state of nature. Without a desert locust invasion, an income of DCU 450 is generated. When damage by locusts occurs, a residual damage of DCU 100 is inflicted, so that the income is altogether reduced to DCU 350. The expected monetary value of this strategy coincidentally tallies with that of market insurance. However, the CE is smaller, because of the income variability in strategy (a_3).

As a consequence, the farmer will prefer market insurance, because it has the highest CE. From a social point of view, forgiving both, self-insurance and market insurance is the most favorable strategy as indicated by the highest expected value. Thus, in the example, the farmer's choice deviates from the socially optimal strategy.

Self-protection

Up to this point, the effects of self-protection have not yet been considered in the decision matrix. As stated above, self-protection aims at reducing the damage probability. In this case, the probabilities assigned to the respective

[20] The CE is calculated using Equations 2.8 and 2.9 using equation 2.7 with r = 2 as the utility function.

states of nature are not fixed, but rather depend on the implemented protection measures.

Different probabilities are reflected in a new decision matrix (Table 14). Besides the probabilities "with self-protection" (p_2), allowance is made for the costs of the protection measures in all the cells of the new matrix. The probability of a locust invasion is reduced ($p_2 < p_1$). The cost of self-protection (C_{SP}) reduces the payoffs in any state of nature, irrespective of the chosen insurance strategy.

When the farmer has the choice to implement a self-protection strategy, the utility maximizing strategy is, of course, the one with the highest CE. The farmer chooses the strategy with the highest CE considering strategies with and without protection measures. If the farmer chooses a strategy with a lower CE, the loss he perceives is the difference in CEs between the implemented and the best strategy.

Table 14: Decision matrix for a farmer implementing self-protection measures

		alternative actions		
state of nature	**probability**	a_1 no insurance	a_2 market insurance	a_3 self-insurance
S_1: no locust	$1-p_2$	$Y_0 - C_{SP}$	$Y_0 - C_2 - C_{SP}$	$Y_0 - C_3 - C_{SP}$
S_2: invasion	p_2	$Y_0 - L_1 - C_{SP}$	$Y_0 - C_2 - C_{SP}$	$Y_0 - C_3 - L_3 - C_{SP}$
CE		CE_1	$CE_2 = Y_0 - C_2 - C_{SP}$	CE_3

Source: own presentation

Example 2

Suppose, the farmer from Example 1 can make use of a self-protection strategy, e.g. by using seeds of fast growing varieties. The farmer has experienced that substantial damage was inflicted on his crops only very late in the growing season. Thus, he might expect from the fast growing varieties a reduction in the probability of severe damage. In this example, it is assumed that the probability is reduced to 0.02. The additional cost for the seeds of fast growing varieties is DCU 10. Table 13, is now interpreted to hold for the case in which the farmer refrains from self-protection. Table 15 represents the decision matrix when the self-protection strategy is pursued. It takes into account the reduced damage probability as well as the costs of the self-protection measure[21].

Table 15: Sample decision matrix with self-protection

		alternative actions		
state of nature	**probability**	a_1 no insurance	a_2 market insurance	a_3 self-insurance
S_1: no locust	0.98	490	430	440
S_2: locust invasion	0.02	40	430	340
E		481.0	430.0	438.0
CE		**400.0**	**430.0**	***437.4***

Source: own presentation

Once self-protection is chosen, self-insurance with a CE of about DCU 437 is the most attractive strategy for the farmer (Table 15). From a social point of view, refraining from insurance at all is most attractive, since it yields the highest expected value. However, the farmer can decide upon self-protection. She or he does not choose the strategy with the highest CE from one matrix only, but the CE maximizing strategy from both. In this example, the optimal farm-level decision will be to buy a market insurance (CE of DCU 440) and refrain from self-protection, because this combination of strategies has the highest CE across Table 13 and Table 15.

The second best strategy is no self-protection plus self-insurance with a CE of DCU 437.5, followed by self-protection plus self-insurance with a CE of DCU 437.4. The difference between the latter CE and that of the best strategy combination amounts to DCU 2.6. This means that when the costs of self-protection were reduced by this amount, self-protection plus self-insurance would become an equally favorable strategy combination.

Putting it differently, the maximum willingness to pay for a self-protection measure that reduces the damage probability to 0.02 amounts to the difference between CEs of the best strategy with self-protection and the best

[21] The impact that self-protection could have on insurance premiums, i.e. a reduction in the premium, is not considered here. It has been observed that insurance companies usually fix their premiums with respect to the expected indemnity payments to a group of farmers and not to individual risks (HAZELL et al., 1986). Individual farmers implementing self-protection are therefore unlikely to benefit from reduced premiums.

strategy without self-protection plus the costs of self-protection, when they were allowed for in the table. In our example this is

$$CE(a_{SP3}) - CE(a_2) + C_{SP} = WTP$$

$$437.4 - 440.0 + 10 = 7.4$$

As a consequence, our farmer would be ready to pay a maximum of DCU 7.4 for the improved seeds.

Perception of public control interventions

By analogy with self-protection, the effect of public control is a reduction of the damage probability. Assuming that the damage probability is 0.1 when no public control is undertaken, Table 13 from the previous example provides a starting point.

What will happen, if a public control policy decreases the probability of a severe damage? Let us assume that public control reduces the damage probability by the factor 5 so that on average only once in every 50 years a severe damage is inflicted. The farmer faces the decision formalized in Table 16. It is essentially the same decision matrix as presented in Table 13, with the only difference that no allowance for the cost of the public control strategy is made.

Table 16: Example of a decision matrix for a farmer with public control being carried out

		alternative actions		
state of nature	**probability**	a_1 no insurance	a_2 market insurance	a_3 self-insurance
S_1: no locust	0.98	500	440	450
S_2: locust invasion	0.02	50	440	350
E		491.0	440.0	448.0
CE		**423.7**	**440.0**	***447.4***

Source: own presentation

If public control is undertaken, the farmer will no longer buy insurance but rather self-insure, because this strategy has the highest CE. This is not surprising, since the insurance premium was calculated using a higher damage probability[22]. Under the assumption that the stated probabilities are objective, the expected value of the farmer's income increases from 440 to 448. Thus, the average increase in the farmer's income accruing from public control amounts to not more than DCU 8. This surprisingly small effect is a consequence of the fact that the farmer chooses coping or mitigation strategies that appear efficient, i.e. that maximize the CE under the given circumstances.

When the farmer can participate in the decision-making on institutionalized control, e.g. by contributing to the funds for desert locust control, the question of his willingness to pay arises. There is not only the choice between alternatives within a single decision matrix. Instead, the alternative with the highest CE by comparing the "with" (Table 16) and the "without" (Table 13) situation will be choosen. The farmer would be willing to pay at most the difference in maximum CEs of both the "control" and the "no control" scenario. In the example, the farmer may contribute at most DCU 7.4 to a public control strategy and be at least as well off as without control. Notably, his maximum willingness to pay is lower than the increase in social benefits (DCU 8) due to risk aversion.

It must be stressed, that the increase of farm income is not necessarily the only benefit of public control. For example, market effects like a price decrease as a consequence of increased supply increase the consumer surplus and hence contribute to enhanced social welfare. The focus in farm level analysis is on the single enterprise. It is assumed that individual suppliers are too small to cause market price changes. Therefore, the market effects are omitted. Also, external costs like health or environmental costs of pesticide application are not included in this calculation. The cost-benefit analysis in section 3.5 will take these effects into consideration.

The example, nevertheless, clarifies the problems that arise from approaches which determine benefits of public control in terms of prevented physical crop loss times price. The underlying assumption of this approach is that farmers cannot adapt to the desert locust risk. In the presented example, this means that only a no insurance strategy would be left. The benefit of public control

[22] If public control interventions reduce the damage probability on a sufficiently large scale, also the insurance premiums would be adjusted to reflect the reduced actuarial premium. The presentation here, however, focuses on the perception of the farmer. Her or his subjective probabilities do not necessarily reflect the risk of that population of farmers for which the insurance company designs the contracts. See also "Focus: Adverse Selection" (p. 37). This may make the insurance unattractive for some farmers.

would be the difference in expected values of the situation with public control (DCU 491) and without control (DCU 455). It amounts to DCU 36 in the example. Taking the coping strategies into account yields benefits of public control of DCU 8, only[23].

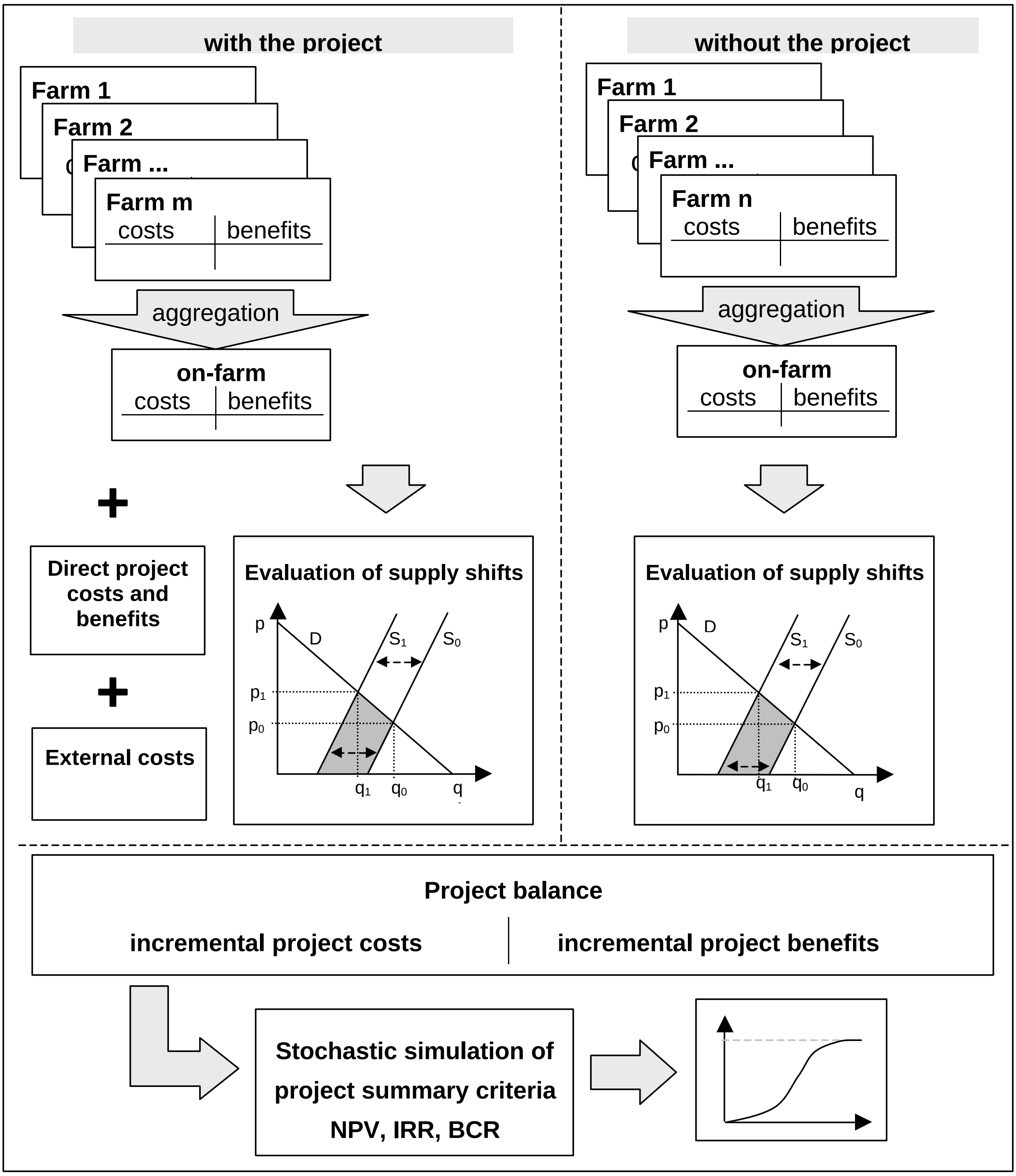
It can be concluded that there is a difference between approaches that do and those that do not allow for on-farm coping strategies. Those strategies omitting on-farm coping strategies overestimate the benefits of public control. The magnitude of differences, however, depends on the assumptions made in the example, regarding both probabilities and costs of coping strategies. The difference between benefit estimates should be interpreted in a qualitative manner as no empirical data were used.

3.5 Analysis at the project or national level

While the scope of the previous section was restricted to the view-point of a single decision-maker on the farm level, the evaluation of intervention strategies on project or national level analyzes the project from the viewpoint of society. A number of additional effects have to be considered. The basic steps of welfare economic analysis were mentioned in section 2.2. They shall be treated here in a more concrete manner with reference to the economics of desert locust management strategies.

[23] This holds free if the input and output prices that were used to calculate the farm income were efficiency prices. Additionally, the given probabilities must be objective and the overall project size must be small, i.e. market prices are not affected.

Figure 6: Schematic presentation of the project level analysis



Source: own presentation

Figure 6 represents the steps for the analysis of locust management projects. Two important dimensions, namely the stochastic and the temporal distribution of benefits and costs, are not represented explicitly in the figure. However, they are included in the analytical framework and will be discussed in detail below. The evaluation of a project is based on the comparison of a scenario “with the project” and a scenario “without the project”, which are represented by the left and right half of Figure 6, respectively. The first step is to draw up balance sheets of on-farm costs and benefits. For a comparison of the scenarios, farm balances must be aggregated in a second step. See 3.5.1 for comments on these steps.

As desert locust damage may be locally severe, local market supply might decrease and market prices might rise. As a consequence, not only producers but also consumers of agricultural commodities bear a share of the costs. These effects can be analyzed with the methodology presented in 3.5.3.

For the scenario with the project, the balance of direct project costs and benefits has to be added to the account. The direct project costs refer to those costs of the intervention accruing to the implementing agency, e.g. salaries, investment in machinery, buildings, operating funds and the like. Direct project benefits are less common, because benefits mostly accrue to the target groups, i.e. farmers. Furthermore, the importance of external effects, e.g. of chemical pesticides, calls for integration into the project account. For the evaluation of external effects, often a sophisticated methodology is necessary, which will be discussed in section 3.6. Benefit and cost components should be summarized for both scenarios. The incremental benefits and costs of the project are obtained by a comparison of the "with project" and "without project" scenarios.

Summary criteria like net present value (NPV), internal rate of return (IRR) and benefit cost ratio (BCR) have to be calculated. Besides the information presented in Figure 6, the calculation of summary criteria needs data on the timing of benefits and costs. The proposed stochastic simulation generates risk profiles of the summary criteria, which yields additional information for the decision-making process. However, the data requirements increase significantly, as the probability distribution of key stochastic parameters is needed. See 3.5.4 for a detailed discussion on risk issues.

3.5.1 On-farm effects and aggregation

The previous discussion has shown that farmers adapt their farm plans to changes in their socio-economic and agro-ecological environment. Public intervention may change the environment directly by offering insurance or other services that would otherwise be unavailable. Similarly, the pursued desert locust control strategy influences the farmer's environment by modifying the desert locust risk. Farmers will adapt their farming decisions to the respective surrounding or at least to their perception of this environment (see Figure 3). Furthermore, it is likely that farmers apply adjustment strategies, which result in a changed pattern of farm resource use, production and input utilization if specific changes in the environment take place due to public intervention. These effects can be very distinct on an aggregated level.

To measure this change, a case/control design is proposed. Detailed farm level information on resource use and production must then be elicited in a region “with the project” and in a region “without the project”. Depending on the *ex ante* knowledge on the kind of changes that are to be expected, a full farm budget analysis or a partial budget analysis is recommended.

A farm budget analysis looks at the inputs and outputs of the whole farm. This comprehensive method should be applied where it is difficult to predict the parameters affected by the farmer's adaptation. Detailed resource use and production data have to be elicited (see upper part of Figure 6). The incremental costs and benefits, i.e. those attributable to the project are obtained by comparing the pattern of resource use and production in the respective scenarios. See section 4.1 for details on the methodology.

If parameters that are affected are known or safely predictable, partial budget analysis can be used to obtain the costs and returns. This limits the scope of analysis to the relevant subset of variables. This approach yields the incremental cost and benefit streams, which are attributable to the project. Some further details are given in section 4.1.

Besides on-farm benefits and costs, the direct project costs and benefits have to be included. These are the on-site costs, which are often costs for starting the project (education, establishment of facilities, purchase of investment goods, etc.) and operational costs (wages, fuel, etc.). Listing the cost items is straightforward once the detailed project plan is available. Here the temporal dimension, i.e. the timing of investment plays an important role and must be considered for in the calculation of the discounted measures of project worth.

Unlike in the traditional approach, it is desirable to include also the risk dimension into the analysis. For example, a high proportion of the operational costs (wages, fuel, and pesticides) depends on the prevailing desert locust populations and is hence uncertain. Ideally, the procedure should account for the linkage of these expenditures with the risky desert locust population. At the same time, the inherent risks of project planning with its assumptions on quantities and prices should be included into the analysis explicitly. In addition to deterministic estimates distribution functions for all important parameters should be used. Triangular distribution functions, for example, can easily be obtained by asking experts for the lowest and highest value the parameter will attain according to their opinion. Furthermore, the most likely value or mode of the distribution must be known to specify a triangular distribution. The project planning staff could act as experts for incorporating the uncertain project cost components. See 4.3 for a detailed description.

Including information on the probability distribution of important parameters enhances the transparency and reliability of results. Experts who assess parameters like adoption rates or prices are forced to contribute more of their knowledge to the decision process by giving a range in which the parameter estimates may vary. It is recommended to incorporate this additional information for all major parameters.

3.5.2 Valuation using efficiency prices

Apart from aggregation, the step from farm level to project level analysis includes the valuation of project inputs and outputs in terms of shadow prices. They reflect the opportunity costs of these goods to the economy. This step is also referred to as economic analysis in contrast to financial analysis, which focuses on the profitability at the individual enterprise level. There is an extensive literature available describing the appropriate methods of obtaining shadow or efficiency prices (CURRY and WEISS, 1994; DINWIDDY and TEAL, 1996; GITTINGER, 1982; MISHAN, 1994).

The notion of efficiency prices is based on the assumption that in an open economy, the border price of a tradable good represents the worth of this commodity to the economy. Any deviation of the market price from the border price plus transportation costs is regarded as a consequence of taxes, tariffs, trade barriers or other regulatory interference. It is recommended to use the border price plus transportation costs to the project site as efficiency price for tradable goods in economic analysis (GITTINGER, 1982).

For non-tradable goods the procedure of obtaining efficiency prices is more sophisticated. As an approximate method, the use of standard conversion factors is recommended by several authors (DINWIDDY and TEAL, 1996; GITTINGER, 1982). The standard conversion factor is obtained by calculating the average ratio of shadow prices and domestic market prices for tradable goods of a certain group. Approximate shadow prices for the non-traded commodities of the same group can be obtained by simply multiplying the domestic market price with the appropriate standard conversion factors.

Within the procedure of project evaluation (Figure 6), the valuation in efficiency prices can be done at different stages. It is possible to evaluate the single farm budgets or the aggregate budgets in terms of efficiency prices and then obtain the project balance directly in monetary terms. Equivalently, the aggregation can be accomplished in physical terms and the valuation in efficiency prices can be done in the balance of incremental project benefits and costs.

3.5.3 Consideration of market effects

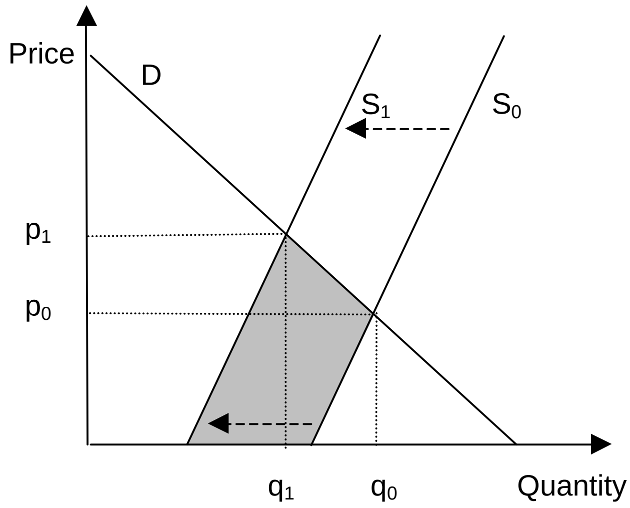
The analysis follows largely the format for project evaluation proposed by GITTINGER (1982). It is suitable for small projects, that have no significant effect on market supply compared to the overall size of the market. This presupposition rules out that the project outputs affect the market in a way that prices rise or fall. However, there are a number of reasons for the assumption that desert locust management decisions have noticeable market effects.

Firstly, local markets in most regions prone to locust invasion are supposed to be poorly integrated. Price fluctuations are not easily transmitted across spatially remote markets and across commodities. Variation in local supply is likely to result in marked price fluctuations. Secondly, desert locusts do harm randomly but spatially clumped. On a local level, supply shocks may therefore lead to a marked increase of market prices of the affected commodities.

Figure 7 shows a market diagram that analyzes the effect of a marked decrease of available produce to sell. On the horizontal axis, the quantity of the commodity is shown, while the vertical axis represents the price. D represents the inverse demand curve, which gives the quantity demanded as a function of the price[24]. It is characterized by a negative slope, which corresponds to decreasing quantities demanded with increasing prices. The "original" supply is represented by curve S_0. The increasing slope of the supply curve signifies the fact that producers will increase the supply with increasing prices. The market equilibrium is attained where the supplied quantity tallies with the demanded quantity at the equilibrium price. The equilibrium point is (q_0, p_0).

[24] **Line D in** Figure 7 represents the *inverse* demand curve, because quantity is given on the horizontal axis and price is given on the vertical axis, although the quantity demanded is a function of price rather than the other way round.

Figure 7: The effect of a production shock



Source: own presentation

When locusts destroy part of the crops, the supply of the affected commodity will be reduced from q_0 to a lower quantity q_1, which leads to a higher equilibrium price p_1. The extent of the price rise depends on the slope of the demand curve D in the neighborhood of the old equilibrium point. The sensitivity of demand to price fluctuations is measured by the own-price elasticity of demand (E_D, see Equation 3.1 and Table 17). The demand for staple foods is often assumed to be inelastic, which means that the demand curve is steeply inclined and a reduction of the equilibrium quantity leads to a greater than proportional price rise.

$$E_D = \frac{\Delta q}{\Delta p} \cdot \frac{p}{q} \qquad (3.1)$$

Table 17: Ranges for the own-price elasticity of demand and corresponding market reactions

completely inelastic demand	$E_D = 0$	A price change does not affect the quantity demanded. The inverse demand curve is vertical.
inelastic demand	$-1 < E_D < 0$	A price change leads to a less than proportional change in the quantity demanded. The inverse demand curve has a steep slope.
elastic demand	$-\infty < E_D < -1$	A price change leads to a greater than proportional change in the quantity demanded. The inverse demand curve has a moderate slope.
completely elastic demand	$E_D = -\infty$	The demand is independent of the price. This corresponds to a horizontal inverse demand curve.

Source: after VARIAN (1999)

After a production shock the equilibrium point (q_1, p_1) is determined by the resulting equilibrium quantity and its corresponding price on the demand curve. The supply curve is shifted to S_1, accordingly.

The welfare implications of such price changes are analyzed using the concept of consumer and producer surplus. Consumer surplus is represented in Figure 7 by the area of the triangle below the demand curve D above the price line, while producer surplus is the area below the price line but above the supply curve. The change of the sum of these areas, which is the change in net social surplus, is a measure of the welfare change. Assuming linear demand and supply curves and a horizontal shift of the latter, the change in net social surplus is represented by the shaded area in Figure 7.

Algebraically, the gain or loss in net social surplus is obtained from Equation 3.2.

$$NSG = (q_1 - q_0) p_0 \left(1 + \tfrac{1}{2} \frac{q_1 - q_0}{q_0 (E_S + E_D)} \right) \qquad (3.2)$$ [25]

Sometimes, however, it is desirable to use separate estimates for the change in producer and consumer surplus, in order to analyze the distributional effect of a production shock. For obtaining a separate estimate for the gain or loss in consumer surplus, Equation 3.3 can be utilized, while Equation 3.4 gives the

[25] after SADOULET and DE JANVRY (1995)

change in producer surplus under the assumption of linear demand and supply curves.

$$CG = \frac{(q_1 - q_0)\,p_0}{E_S + E_D}\left(1 - \tfrac{1}{2}\,\frac{(q_1 - q_0)E_D}{q_0(E_S + E_D)}\right) \qquad (3.3)$$ [26]

$$PG = (q_1 - q_0)\,p_0\left[1 - \frac{1}{E_S + E_D}\left(1 - \tfrac{1}{2}\,\frac{(q_1 - q_0)(2E_D + E_S)}{q_0(E_S + E_D)}\right)\right] \qquad (3.4)$$ [27]

The initial equilibrium quantity is q_0, q_1 the new equilibrium quantity and p_0 the initial equilibrium price. E_S and E_D represent the own-price elasticity of supply and demand, respectively. With the help of these formulas, the respective welfare changes are easily obtained when the necessary information on supply and demand elasticities are available.

While the availability of appropriate estimates for demand and supply elasticity is itself a demanding requirement for many situations in the developing world, it might be even more difficult to find the appropriate initial equilibrium quantity. As the aim is to analyze the welfare change in a with/without the project comparison, the supply quantity and prices have to be taken as given in a specific year or season.

It may be difficult, however, to determine the baseline supply and prices. Supply levels may vary significantly due to the differences in agro-ecological, climatic and economic factors which influence the yield levels. See the Figure 4 and Figure 5 (p. 34) on the cereal production of Morocco and Sudan for an example. The high production in the plague year of 1988 in both countries suggests that desert locust plagues do not necessarily and directly lead to reduced national cereal supply. Due to the dependence of agricultural production as well as desert locust development on humid conditions, it is likely that desert locust damage and low national supply are negatively correlated. An analysis that ignores the negative correlation would overestimate the losses due to desert locust damage, because two negatively correlated risks tend to neutralize each other. This underlines once more the importance of utilizing the correct price and supply estimates, which are those of the particular season without the desert locust damage.

---

[26] after NORTON and DAVIS (1981)

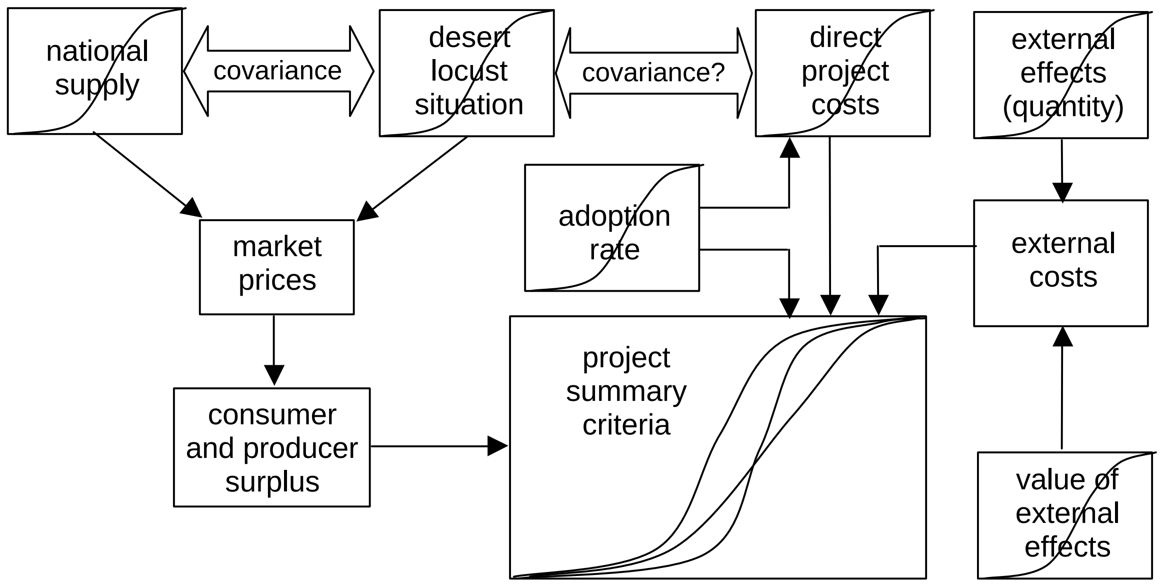
For these reasons, the market effects should be considered within the framework of stochastic simulation in a way that makes allowance for the covariance of factors determining the national supply. The need to pay special attention to the implications of localized severe supply shocks has often been emphasized, especially as a critique to economic evaluation studies. The thorough application of the welfare analytical methodology accounts for the implications of a supply shock by calculating the consumer and producer losses resulting from supply shifts.

3.5.4 Risk issues

The necessity of considering risk for the benefit and cost components has been pointed out previously. Basic tools for risk analysis have been introduced in section 2.3. More specific methodologies for obtaining information on stochastic parameters and stochastic analysis are discussed in sections 4.3 and 4.4, respectively.

Figure 8 provides an overview of the stochastic components and their interdependence. The figure can also be read as a flow chart, which acts as a backbone to the simulation procedure, e.g. for an evaluation of public control. The stochastic incidence of desert locust damage is the key source of uncertainty – at least on a local level. At the same time other components, like the overall supply on the national market, are important factors of uncertainty. It is likely that the probability distributions of these two factors exhibit a significant covariance.

Figure 8: Uncertain components of project benefit and cost



Source: own presentation after NORTON and DAVIS (1981)

It is known that a great number of factors contributes to yield variation, with some of them having a widespread impact. Take rainfall as an example. Even more than desert locust plagues, drought has a strong impact on huge agricultural areas in a region, which results in even more distinct variations in the supply of agricultural commodities.

When different sources of risk are considered, it is important to take into account the covariance among these risks. Judging from the figures on the cereal production of Morocco and Sudan (see Focus Box on p. 34), the desert locust plague of 1988 had no visible impact on *national* production. Furthermore, desert locust plagues coincided with higher than average yields. Although there is not yet enough evidence, it seems likely that humid years are positively correlated with desert locust invasions. As a consequence, a production shock through desert locusts is likely to be mitigated by higher national production in the same season while locally severe production shortfalls may occur. This should be taken into account by the correct choice of base prices and supply assumptions for the calculation of consumer and producer surplus. Correct base prices and supply levels are those prevailing in the respective season without the desert locust damage (see 3.5.3). The stochastic dimension of direct project costs has to be modeled with respect to the correlation with the desert locust situation, especially for control strategies.

Consumer and producer surplus and the direct project costs enter the stochastic simulation of project summary criteria. Where significant external effects are to be expected, these must be taken into account as well. Because the quantification of effects is often difficult, it may be helpful to incorporate the quantitative estimates of external effects as stochastic parameters. More precise stochastic information on these uncertain estimates can be incorporated by using distribution functions. The triangular distribution is the simplest, because experts would only have to state the minimum and maximum values and the most probable value to fully specify the distribution function (see section 4.3).

External effects of the intervention can be quantified and used as stochastic parameters for determining a probability distribution of external costs. This procedure accounts for the uncertainty that surrounds the estimation with direct and indirect methods. For example, the contingent valuation method yields a range of bids from a survey, which can be interpreted as a probability distribution of the willingness to pay for the good in question. It is straightforward to consider the probability distribution in the calculation of the project worth, instead of reducing the information to a single estimate.

Finally, assumptions on the adoption rate should be considered as uncertain estimates, since these often have crucial influence on direct project costs or other project components. Here again, experts should state not only a single point estimate but reveal more of their knowledge by specifying a probability distribution function for the adoption rate.

Summing up, an evaluation of desert locust management strategies must include uncertainty of a variety of parameters. Some of the parameters are stochastic due to their nature, as the national agricultural production and the desert locust situation. Other variables are deterministic in the real world, but limited methodological means yield only uncertain estimates, e.g. willingness to pay for environmental goods and quantitative measures of environmental damage. For the latter group of variables, incorporating them with a probability distribution is more realistic and transparent than just putting in a point estimate.

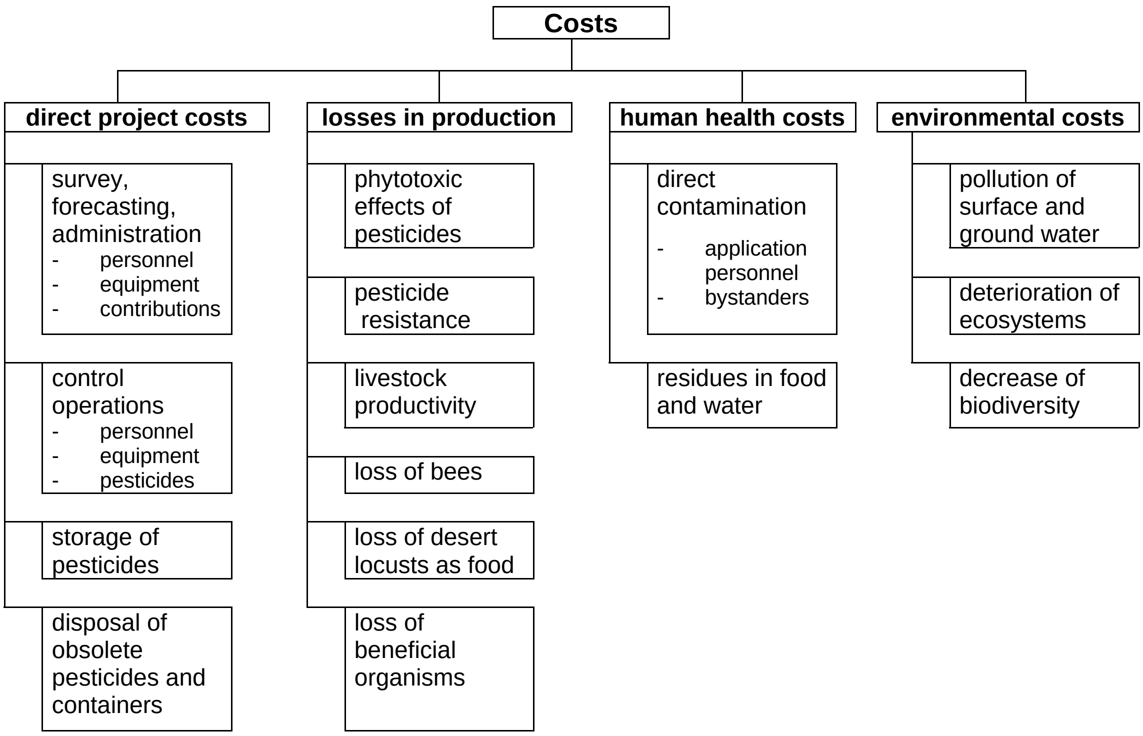
Regardless of the source of uncertainty, stochastic information can be summarized with the means of stochastic simulation. The resulting risk profiles for alternative intervention strategies can then be compared with regard to both mean performance and risk implications by applying stochastic dominance criteria (section 4.4). This procedure makes risk considerations transparent in decision-making and avoids any wooly discussion on how to handle the uncertainty when only single value performance criteria are available.

3.6 Incorporation of externalities

An additional component of project level analysis is the inclusion of all external effects. External effects are basically economic effects of one agent's behavior on another's well-being, where this effect is not reflected in market transactions (LITTLE and MIRRLEES, 1974). In this sense, the benefits farmers derive from a public control strategy can be understood as positive external effects of the control activities, because farmers do not pay for this service. However, farmers belong to the targeted group and their stake is considered in the project account.

Particularly public control is supposed to have marked external effects. Figure 9 gives an overview of the different cost components of a public control strategy.

Figure 9: Potential and actual cost components of public control



Source: own presentation

The first branch lists the direct project costs. The other cost components are regarded as external costs. Attempts have been made to provide all conceivable cost categories.

In Figure 9 the effects are grouped with regard to the applicable valuation methods; a more systematic overview of the environmental effects is given in EVERTS and BÂ (1997). The focus here is on the methodological aspects, the discussion of particular effects is presented in Appendix A-2.

Table 18 gives a schematic overview for the economic evaluation of external effects. The first step is the identification of relevant effects. For pesticides, a wide variety of possible effects has been identified (Figure 9). The *relevant* components must be identified for each specific case, because an evaluation is often time-consuming and should focus on the important points. At this early step, the cause-effect relationship must be thoroughly established, in order to achieve credible results.

Quantification is often more difficult than just identifying effects. However, it is indispensable to assign a meaningful value to the increase or decrease in the quality of an environmental good. These first two steps usually are accomplished by natural scientists, who have complete command over the necessary methodology. It is only at the third step of monetary assessment that economic methods are applied for eliciting a value for the change in the provision of an environmental good.

Table 18: Steps for an economic evaluation of external effects

Step	Example
1. Identification of relevant effects with its cause – effect relationship	Effect of a certain insecticide on bird population, either mortality through direct intake, through the food chain, or through reproductive effects, respectively.
2. Quantification of the effect	Reduction of bird population in a given area and over a certain period (surveys, statistics etc.)
3. Monetary assessment	Evaluation of losses in bird population, different approaches feasible: **a. production value** "which contribution to agricultural or other types of production do birds have" **b. conservation value of species** "how much worth is the conservation of a certain species from being extinct"

Source: adapted from Pesticide Policy Project (unpublished)

The valuation of environmental goods is a special task, because most environmental goods are public goods, which are not traded in markets. While the economist usually works with market prices, special valuation methods are applied for environmental goods. Some of these methods are mentioned in Table 18.

1. Measuring the production value of an environmental good or service

   Here, the environmental good in question is valued in terms of its contribution to the production of marketed goods. This is taken as an estimate for its value. See also section 4.2.1 for methodological aspects.

2. The contingent valuation method

   The contingent valuation seeks to infer the value individuals ascribe to an environmental good by special survey techniques. It sets up a hypothetical market for a clearly defined change in the provision of this good. Respondents are then asked for their willingness to pay for maintenance of access, or their willingness to accept a compensation for foregoing the access to the specified good.

The production value or dose-response-approach can be applied for valuing many of the external effects listed in Table 19. The approach is especially useful to value losses in production, e.g. losses in livestock and bees, but also for the health costs as far as the application personnel is concerned. The main advantage of this method is the reliance on established markets, the prices are not disputed. However, the method looks only at the productive aspects and leaves out the value individuals could derive from the continued existence of certain species or of the balance of an ecosystem.

Due to its hypothetical market scenario, the contingent valuation method (CVM) is very versatile and can also measure the appreciation of not yet existing services and goods. Its application for measuring the farmers' appreciation of an insurance system was mentioned before. A detailed description of the procedure can be found in section 4.2.2. Appendix A-5 gives an example of a CVM survey form.

Table 19: External effects and suitable methods for valuation

Phytotoxic effects	Production value
Pesticide resistance	Production value (additional control costs)
Livestock productivity	Production value (cost of lost livestock, reduced increase in weight, reduced fecundity) CVM – willingness to pay of pastoralists for environmentally friendly desert locust control
Loss of bees	Production value CVM – willingness to pay of beekeepers for refraining from harmful pesticides
Loss of desert locusts as food	Market price Surrogate market approach: Value of equally proteine-rich food items
Loss of beneficial organisms	Production value (costs of lost production due to increased pest incidence or costs of mitigation activities like pest control)
Human health costs	Production value (lost labor days and cost of treatment)
Residues in food and water	Market price (of produce that has to be withdrawn from the market due to exceeding maximum residue levels) Avoidance costs (additional costs consumers incur for getting alternative food and water) Mitigation costs (costs for cleaning-up the drinking water)
Pollution of surface and ground water	Mitigation costs (costs for cleaning-up) Willingness to pay (the consumers' appreciation of clean natural resources)
Decrease of biodiversity	Willingness to pay (the consumers' appreciation of biodiversity, for its mere existence or for its possible use in the future)

Source: own presentation

Table 19 gives an overview of the methods that are suitable for valuing the external effects which were identified for public control. The brief list indicates that for all effects, economic valuation methods are available. In real world applications, the hurdle lies often with the first two steps: identification and quantification of external effects. Especially for the important case of external effects of chemical pesticide application, many of external effects have been identified but a reliable quantification is often lacking[27]. Thus in this field the information base will have to be augmented and improved.

Notwithstanding these difficulties, the incorporation of external effects is a crucial component of project level analysis. From the viewpoint of the society at large external effects are costs (and rarely benefits) that contribute to the project's overall effect.

3.7 Inter-country implications

The scope of CBA is usually constrained to a national economy. This is a sensible approach for the evaluation of desert locust management, because it provides profitability criteria that can guide decision-makers on the national level or sub-national decision units. Nonetheless, effects of economic activities may reach far beyond the borders of a single country. Most obvious examples are transboundary pollution problems like acid rain or global warming. In the context of desert locust management, early desert locust control is claimed to have marked off-site effects in the sense that control reduces desert locust populations and disturbs continued breeding, hence reducing the probability of swarms invading neighboring countries. This kind of externalities has made desert locust control a task that is more or less internationally coordinated. Actually, the current public control strategy is fundamentally based on the assumption that early control in the breeding habitats has positive external effects large enough to compensate for the costs of control on average. Notably, costs and benefits are not necessarily evenly distributed among countries. By analogy of transboundary pollution problems, the issue of border crossing effects shall be discussed.

HANLEY et al. (1997) build their analysis of transboundary pollution problems on two issues that primarily refer to rather technical characteristics: the uniformity of damage and the uniformity of mixing.

Uniformity of damage

Due to different physical and economic factors, specific countries suffer varying damages from pollution (HANLEY et al*.,* 1997). In our context countries have varying levels of damage from desert locusts, i.e. they derive different benefits from desert locust control. The bio-technical factors influencing this damage potential range from the geographical and geophysical

[27] See also Appendix A-2 for specific information on external effects of chemical control interventions.

characteristics, rainfall and wind patterns, cropping systems and natural vegetation, to the available management strategies. Economic factors determine farmers' coping strategies, the value of damaged crops, impacts on food markets, rural labor and input markets. Hence, the damage of desert locust control is not uniformly distributed across countries.

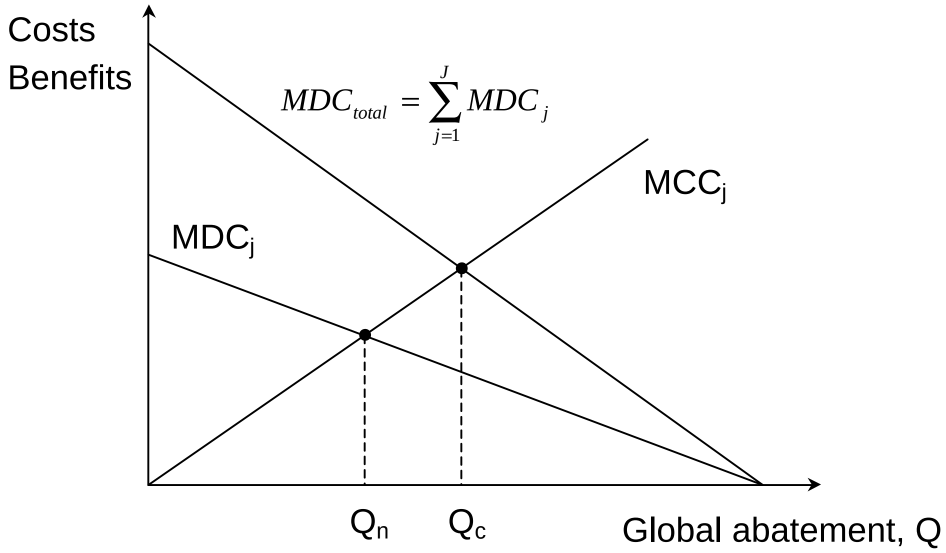
Uniformity of mixing

In the transboundary pollution context, uniformity of mixing refers to the extent to which the emissions from different countries contribute to overall pollution potential. The physical factors that determine the transport rates of pollutants may be a source of non-uniform mixing, e.g. with air pollutants causing acid rain. Global warming is regarded as a consequence of uniformly mixed pollutants (HANLEY et al., 1997). Applied to the desert locust problem, non-uniformity of mixing prevails: the invasion area may be a source of desert locust populations only under plague conditions, whereas desert locust populations may come forth in the recession area all the time. More specifically, the area around the Red Sea is thought to be the source of many major desert locust plagues, whereas countries such as Morocco and Algeria are mainly invaded by swarms and - during recession periods - not the source of new ones. In a way, Morocco and Algeria might thus be regarded to contribute only a minor share to the desert locust damage potential, compared e.g. to Yemen and Eritrea.

Economic implications

Desert locust swarms migrating from one country to another might be regarded as a kind of international negative externality. In a national economy, the government can intervene for example with taxes to internalize those effects. In the case of international externalities, no supranational government exists that can simply internalize transboundary externalities (HANLEY et al., 1997).

Figure 10: Non-cooperative and full cooperative outcomes of public desert locust control



Source: adapted from HANLEY et al. (1997, p. 167)

In Figure 10, the marginal damage costs[28] of country j (MDC_j) are drawn as a function of global control efforts. Domestic marginal damage costs (MDC_j) decrease with increasing control efforts Q. With increasing control efforts, domestic marginal control costs (MCC_j) increase, because at higher control levels, it will be increasingly difficult to find swarms and control the remaining insects. Note that these control costs embrace not only the “internal costs” for survey and spray operations but also the negative externalities like productivity losses in activities other than farming, health and environmental costs. When each country j acts purely selfish, it chooses the level of control efforts Q_n so that marginal domestic damage costs MDC_j equals marginal domestic control costs MCC_j. Q_n is the level of control efforts in a non-cooperative outcome, the Nash equilibrium[29]. Total marginal damage costs for all affected countries MDC_{total} is the sum of each countries marginal damage costs and thus higher than the individual countries MDC_j. If countries could agree to cooperate, global control efforts Q were increased until MCC_j equals MDC_{total} for each

[28] The term marginal (damage) costs refers to the first derivative of the cost function and denotes the additional cost of an increase in one unit. In economics the concept of marginality plays an important role. The optimal level of damage is determined by the point where the cost of an additional unit of abatement activity is just recovered by the additional (marginal) benefit.

[29] These considerations stem from game theory for static games, i.e. those in which players make simultaneous decisions. Informally, a Nash equilibrium is defined as the set of best strategies for each player given that the other players choose their respective best strategies. No player has an incentive to deviate from his predicted action in a Nash equilibrium (HANLEY et al., 1997).

country.The cooperative solution Q_c is attained, which is Pareto superior[30] to Q_n from a global point of view.

However, some countries are worse off, because their marginal control costs exceed the benefits (MDC_j) and they have incentives to quit cooperation. The cooperation is thus not an equilibrium for all affected countries except those countries that are worse off in a cooperative outcome, are compensated by those benefiting from cooperation (HANLEY et al., 1997).

For the desert locust control problem, this means that (a) marginal costs of control efforts vary and (b) marginal costs due to desert locust damage vary among countries and (c) a cooperative outcome that optimizes the level of global control efforts can be obtained only through side-payments.

For example a pair of countries 1 and 2 optimize their level of desert locust control so that

$$MDC_j = MCC_j \qquad j = 1, 2.$$

When $MDC_1 > MDC_2$ (implying also that $MCC_1 > MCC_2$ in the Nash equilibrium) it is a welfare improving policy for country 1 to support control activities in country 2. A unit of damage in country 1 can be prevented at lower costs when control activities take place in country 2. However, even with side-payments, incentives to breach mutual agreements by collecting side-payments without ensuring the agreed upon control efforts remain. This postcontractual risk must be accounted for in the agreements. Enforcement of signed agreements by sanctions must therefore be possible (HANLEY et al., 1997). In the desert locust context, coordinating activities by FAO and regional organizations may help to cope with this problem. Also, repetitive contracting is a possible solution to this problem. The sheer impossibility of controlling the contractors' combating activities may still remain an important drawback, however.

The analytical framework presented in chapter 3 results in country specific net benefit measures of alternative strategies that can be used in this context to determine the maximum amount the country could contribute to the funding of the desired management strategy in other countries. In a country, for which public control proves a dominant strategy, the difference in NPV to the second best strategy is the maximum amount the country can contribute in a bilateral or multilateral fund for promoting this strategy, e.g. preventive desert locust

---

30 See Appendix A-1 for the concept of Pareto optimality.

control. Conversely, a country with a different strategy yielding the highest NPV among the alternatives, would incur losses if public control is chosen. These losses amount to the difference in NPV between the best and the public control strategy. It follows that these losses are the minimum amount this country must receive from the gainers of a multi-national control strategy to take part in their scheme.

Due to the uncertainty connected with contracting, the willingness to pay of a country has to be discounted for reasons of *a priori* unknown control efficacy. And, conversely, the recipients of side-payments may insist on higher payments due to the *a priori* uncertain costs of control on the one hand and the uncertainty on incoming payments on the other. These considerations might impede a cooperative solution, although regional and supra-regional organizations have a potential to overcome these difficulties. For example Algeria and Morocco have agreed on cooperation with other members of the northwest African regional commission as well as with Mali and Niger. The former countries support the latter through field activities and financial and pesticide assistance (JOFFE, 1995; SHOWLER, 1999).

Cooperation for reinsurance

Besides a public control strategy that ultimately relies on cooperation of the affected countries, insurance strategies could at least benefit from cooperation in the form of mutual re-insurance among countries within different regions. However, the effects are probably not so marked as those for public control. Cooperation is not a necessary condition for effective insurance strategies. Instead, reinsurance can be purchased on the national or international insurance market, when the insurance scheme meets the requirements of the market (GUDGER and AVALOS, 1986).

BENSON and CLAY (1998) propose mutual reinsurance among affected countries for drought insurance. However, in desert locust plague years, many affected countries will incur losses at the same time or within a short period. Mutual reinsurance only makes sense, when other, possibly negatively correlated risks are included in the insurers' portfolios.

The discussion of transboundary implications of desert locust management strategies concludes the concept for economic evaluation of desert locust management interventions. The framework has been developed from the farm level to the project or national level and has been completed by consideration of the international level. The following chapter provides additional background information on the methodologies, which were only broached in this chapter.

4 Methodology of data collection and analysis

The concept discussed in the previous chapter emphasizes the importance of on-farm adaptation (Figure 3, p. 31). As these adaptation strategies are diverse and depend on local knowledge and practices, the most important data source is the farm-household. Depending on the type of data and the study design, different methods of eliciting data must be utilized. It was proposed to analyze the profitability of insurance on the farm level by means of a contingent valuation survey. The analysis from a social point of view needs more detailed information on farm resource use and production. These can be obtained from a comparison of more or less detailed farm budgets in a case control design study.

The prominent role of risk in desert locust management calls for a formal consideration of key stochastic parameters. Information on the probability distribution of the stochastic variables has to be available. The visual impact method is proposed for obtaining this kind of information from farmers. Tools for elicitation and analysis of stochastic data are described in sections 4.3 and 4.4. For the combination of farm budgets and information on stochastic parameters, the reader is referred also to the illustrative example in chapter 5.

4.1 Farm budget analysis

In most agricultural development projects, it is intended to increase agricultural productivity. Detailed information from the farm level is necessary. A comprehensive overview for the information to be collected for farm investment analysis in the context of agricultural project appraisal is given in Table 20.

Table 20: Principal elements of farm investment analysis

Farm resource use
Land use (calendar, crop rotation)
Labor use (annual labor requirement by crop, distribution of labor by crop and month, hired labor, family labor, off-farm labor).
Farm production
Crop and pasture production (yield and carrying capacity)
Livestock production (herd projection, composition, purchases and sales, herd productivity, feed requirements and production)
Valuation (farm-gate prices, value of crop and livestock production, incremental residual value)
Farm inputs
Investment (in physical and monetary units)
Operating expenditure (for crops, for livestock)
Incremental working capital

Source: after GITTINGER (1982)

The approach used by GITTINGER (1982) includes off-farm labor and off-farm income. This avoids the difficulty of stating the opportunity cost of family labor explicitly. Instead the alternative utilization of labor in on-farm or off-farm activities is directly considered in the budget. It also accounts for the close relationship of household consumption and resource allocation decisions with the farming enterprise, which is particularly important in small-scale farming systems or subsistence farming. For example, farm income could be complemented by off-farm income generating activities to diversify the income sources. The assessment of project impacts must cover the farm-household as a decision unit especially when the total household income is a targeted. For these reasons, off-farm income is included in the farm budgets in accordance with the format proposed by GITTINGER (1992, p. 130).

Based on the detailed information listed in Table 20, farm budgets for two scenarios ("with" and "without" the project) can be set up according to the format shown in Table 21. The farm budget should list the physical quantities of inputs and outputs in order to facilitate the valuation in both, farm-gate price (for the farm investment analysis) and efficiency prices for economic analysis. While a valuation in farm-gate prices yields information on the profitability of a new strategy on the farm level, the valuation in efficiency prices is needed for project evaluation as explained in section 3.5.2.

Table 21: Outline of a farm budget

Item	physical units	price	value
Inflow			
Crops	(tons)	(per ton)	
Beans			
Maize			
Sorghum			
...			
Livestock	(heads)	(per head)	
Cattle			
Sheep			
…			
Off-farm income			
...			
Total inflow			
Outflow			
Investment			
Incremental working capital			
Operating expenditure	(kg)	(per kg)	
Seeds			
Fertilizer			
Hired labor			
....			
...			
Total outflow			
Net benefit			

Source: after GITTINGER (1982)

The net incremental benefit attributable to the project is obtained by comparing the farm budgets of the case and control group. The strength of this method is that all activities are considered and a comprehensive analysis is possible. On the other hand, the data requirements are accordingly high.

Partial budgeting

Partial budgeting has less comprehensive data requirements compared to the whole farm budget approach. It reviews only those cost and benefit components that are directly affected by a change in the farm plan (KAY, 1986). It is usually based on the information of natural scientists and agronomists, who predict the effects of a proposed or assumed change in agronomic practices on the relationship between input use and output.

In a case/control study design, different agronomic practices can be identified by the means of a survey. It is crucial to demonstrate that different practices are the result of the public intervention strategy that is to be evaluated. Hence, partial budget analysis is recommended only if the change in the financial plan is safely predictable. Partial budgeting directly yields the net change in input and output, which can be easily summed up across crops and regions in order to compute the aggregated impacts.

Table 22 shows a common format for partial budget analysis. In the left column the additional costs and the reduced income are listed. Their sum represents the total costs of the change. The right column contains the items that produce additional income or reduce costs. The sum of this column gives the total benefits of the projected change. Subtracting the sum of the left column (A) from the sum of the right column (B) yields the net return of the farm plan change.

Table 22: Format for partial budgeting

Partial budget

Proposed change: buying market insurance for the whole cropped area (5 ha), reduction of off-farm income generating activities and intensification of farm production

Additional costs:			**Additional income:**		
Insurance premium	5 ha	$ 400	Yield increase	70 kg/ha	$ 350
Fertilizer	100 kg	$ 80			
Reduced income			**Reduced costs:**		
reduced off-farm employment		$ 200	Self insurance	$ 80 /ha	$ 400
A. Total annual additional costs and reduced income		$ 680	**B. Total annual additional income and reduced costs**		$ 750
			Net change in profit (B-A):		**+ $ 70**

Source: adapted from KAY (1986)

Collecting data on both physical quantities as well as monetary values facilitates the step of shadow pricing for economic analysis. The data can be collected using surveys among farmers or participatory rural appraisal methods.

4.2 Methods for valuation of non-marketed goods

In market economies usually the price mechanism is the signal that guides production and consumption decisions. But due to market imperfections, not all amenities are traded in markets and thus have no observable prices. This is also true for the public service of early control as practiced so far. Moreover, environmental goods like clean water, air or biodiversity are public goods, for which market prices are unavailable.

Methods that aim at obtaining a value for this kind of amenities are usually divided into two approaches: direct and indirect methods. Indirect methods seek to draw conclusions from existing markets for a similar good or a good in which the value of the amenity is reflected (HANLEY and SPASH, 1993). Direct methods seek to infer the value attributed to an amenity directly from individuals by revealing their preferences.

4.2.1 The dose-response approach

In a *dose-response approach*, the bio-technical link between output quantity or quality of a production process and an environmental input is utilized. This is why this method is also known as the production value approach. As a first step the physical dose-response function must be established. This means the technical or bio-technical relationship between the environmental good or service as an input and a marketed product as an output of a production process. The information must be provided by specialists for the bio-technical relationship of the particular production process.

In a second step, an economic model is applied to predict the economic impact of a change in the level of the public good based on the dose-response function (HANLEY et al., 1997). The traditional model or “ad hoc” approach simply takes crop yield change times price as an estimate for the economic value. When the quantity change is small in comparison with the market, this simplification is permissible. But sizable quantity changes have a marked price effect and the welfare effects in this case are more complicated. Equilibrium models using linear or quadratic programming or econometric models must then be applied to predict the effects (HANLEY and SPASH, 1993).

4.2.2 The contingent valuation method (CVM)

The CVM is applicable for the valuation of a wide range of commodities and has been frequently used in environmental and resource economics although it has been discussed controversially (MITCHELL and CARSON, 1989). Its main advantage is that it values public goods even if the above methods fail because no related market behavior can be identified. CVM is capable of measuring all components of the total economic value listed above. The approach uses surveys in which respondents are asked to state either their maximum willingness to pay (WTP) for a defined increase in the level of provision of a public good or their minimum willingness to accept compensation (WTA) to forgo such an increase. Alternatively, the WTP to forgo a decrease or the WTA compensation to accept the decrease may be determined. In many cases the level of quality or quantity of a public good is determined by a third party, e.g. the government, and the valuation inferred from the respondent refers to his Hicksian equivalent or compensating surplus (HANLEY et al., 1997).

Conducting a CVM survey is divided into the following six steps:

1. *Setting up the hypothetical market*

   First, a hypothetical market for the public good in question is set up. This step encompasses a thorough description of the good and the intended change in quality or quantity, which sets up the reason for payment. The bid vehicle, i.e. the modality of payment (income taxes, lump sum payment, annual or entrance fee) must be explained. The respondent must be informed how the decision whether to implement the project is made and which groups would pay (HANLEY and SPASH, 1993). It is important to depict a realistic situation and to choose a reasonable payment modality. The survey instrument is usually a questionnaire that should be filled in during a personal interview (MITCHELL and CARSON, 1989).

2. *Obtaining bids*

   In this step, the respondent is actually asked to state her/his maximum WTP for an improvement or, alternatively, the maximum WTP to prevent a deterioration. Similarly, also the minimum WTA to forgo the improvement or to accept the deterioration may be asked for. See below for a comparison of the WTP and WTA format. The question itself can come in several forms.

   - Bidding game: Increasing amounts are suggested to the respondents until their maximum WTP is reached (HANLEY and SPASH, 1993).
   - Closed-ended referendum: A single payment is suggested, to which respondents either agree or disagree (yes/no reply). The analysis of those dichotomous choice surveys is more complicated than the others, since special techniques must be applied for deriving an average WTP from the binary answers. Additionally, a larger sample size is needed (HANLEY et al., 1997).
   - Payment card: A range of values is presented on a card which may also be related to the share of public expenses the respondent already pays for similar public goods.
   - Open-ended question: Individuals are simply asked for their maximum WTP without suggesting any value. Where respondents have no experience in trading with the good in question, they find it relatively difficult to state their WTP (HANLEY and SPASH, 1993).

3. *Estimating average WTP/WTA*

   For the closed-ended referendum format, a sophisticated method for calculating the average WTP or WTA is necessary. Its application can be found in HANLEY et al. (1997). For all other questionnaire formats, the calculation of mean and median WTP or WTA is straightforward. An issue at this stage is the omission of "protest bids", i.e. unusually large or low bids which might not reveal the true valuation of the respondent and may have an oversized effect on the mean. The median will not be affected by outliers (HANLEY and SPASH, 1993).

4. *Estimating bid curves*

   This step tries to identify the determinants of WTP/WTA bids. In a regression analysis, the correlation of a number of independent variables (e.g. income, age and education) on the dependent (WTP/WTA amount) is established. Also a regression against the quantity or the level of quality of the commodity is of interest. This may provide hints at the validity of the CVM exercise, when results are compared to theoretical evidence (HANLEY and SPASH, 1993).

5. *Aggregating data*

   By aggregating the sample mean WTP or WTA, a total population figure is obtained. When the sampling procedure was subject to biases, simply multiplying the sample mean by the number of households will lead to incorrect results. Then the regression equation can be used to estimate the mean WTP or WTA using the population means for the independent variables (HANLEY and SPASH, 1993).

6. *Evaluating the CVM exercise*

   This step aims at appraising the overall performance of the CVM exercise and tries to asses the impact of various sources of errors and biases (HANLEY et al., 1997).

An in-depth description of the contingent valuation method is not possible here. Some critical issues are briefly discussed in Appendix A-3. For further details the reader is referred to textbooks on this methodology (HANLEY and SPASH, 1993; MITCHELL and CARSON, 1989).

A thorough evaluation of a CVM survey needs some insight into basic statistic methods, e.g. linear regression models. It is recommended to utilize the skills of an experienced environmental economist in any such survey.

4.3 Data on risky parameters

Nothing has yet been said on how to obtain the probabilities the decision-maker imputes to the individual states of nature. For a small set of outcomes, the decision-maker might be asked to state his degrees of belief, but this will be constrained to the case of three or four alternative states of nature. Moreover such procedure necessitates a certain understanding of probabilities on the side of the decision-maker. Here the visual impact method is presented as an interesting way of obtaining probability estimates from decision-makers that are not familiar with formal risk estimation. A second simple method allows the inclusion of expert assessments about the risk of certain variables.

Visual impact method

The visual impact method can be used to capture the subjective probabilities for more than five alternative outcomes and facilitates the process of reassessing the choice. Usually, the possible states of nature are listed in the left column (Table 23). The decision-maker is asked to allocate a number of counters like ordinary match-sticks to the individual states of nature according to the imputed probability. This means, when the assessor believes one outcome is twice as likely as another, she or he should allot twice as much of the counters onto the field representing the event. The assessor should also be informed that she or he should not necessarily use all counters and that more counters are available if needed. The probabilities are then calculated as the relative frequencies of the allocated counters.

Table 23: Example of a visual impact table for different desert locust damage scenarios

State of nature	Counters	Count	Probability
no desert locust damage	●●●●●●●●●●●●●●	14	14/20 = 0.7
light damage	●●●●	4	4/20 = 0.2
severe damage	●	1	1/20 = 0.05
catastrophic damage	●	1	1/20 = 0.05
Totals		20	1.00

Source: adapted from HARDAKER et al. (1997)

The advantage of this procedure is the visual representation of the probabilities and the ease of rearrangement until a satisfactory distribution is obtained. The important property that the probabilities of a complete set of discrete states of natures must sum up to unity, is ensured by calculating the probabilities from counter frequencies. The accuracy of probability estimates can be increased through providing more counters but is limited by the capacity of the assessor, though.

This approach can be easily extended to obtain distributions for single continuous variables. The range of the distribution must be obtained first by asking what the assessor believes is the highest and lowest possible value, such that he/she would be very surprised if the value were actually beyond or below the stated bounds[31]. This range may then be divided into a reasonable number of intervals (e.g. 5-7) which are entered into the visual impact layout. Again, the assessor is asked to allocate the counters according to his beliefs and the discrete probabilities are calculated for the intervals. Finally, a cumulative density function can be obtained by calculating the cumulated probabilities, and smoothing a curve through the data points. Smoothing may be done by hand or by using computer software[32]. For many purposes, a smoothed curve is not necessary, because software for Monte-Carlo-Simulation (section 4.4) like @Risk accepts also discrete estimates for continuous distributions.

Alternatively, continuous distributions can be obtained by directly asking for the fractiles of the distribution. The so-called judgmental fractile method is more abstract and requires a deeper insight into the concept of probabilities than the visual impact method on the side of the assessor. The gentle reader is referred to HARDAKER et al. (1997) for a detailed description of the judgmental fractile method.

Simple methods for expert risk assessment

It is a commonplace, that deterministic information is rather the exception than the rule. Talking about a single estimate for a parameter implies in most cases that we talk about the mean or the expected value of a parameter, which in fact stems from an underlying probability distribution. Throughout the

---

31 The visual impact method measures the probabilities with a maximum resolution of 1/n, where n is the number of counters used. Allowing for the rounding procedure implicit in the approach, the maximum probability of exceeding one of the stated bounds is 1/(2n) (HARDAKER et al., 1997, p. 36).

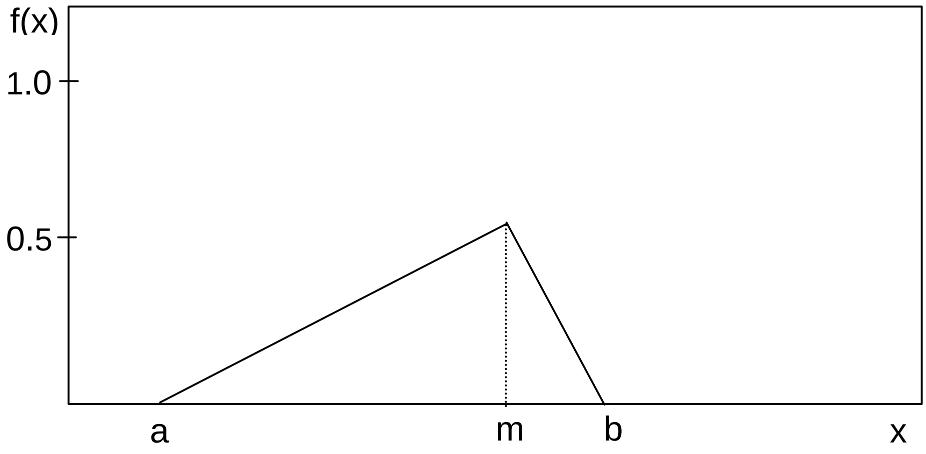
32 HARDAKER et al. (1997) suggest BestFit by Palisade Corp. for this purpose.

preceding chapters, a number of reasons are given for considering the stochastic dimension of important variables explicitly and formally in the analysis. In addition, the methodology and the tools for a trouble-free inclusion of the stochastic dimension even in complex analyses are available (section 4.4). This suggests that it is sensible to include information on the distribution of important parameters into the project analysis.

While the most important parameters like yield levels demand a thorough elicitation of probabilities, more convenient methods for less important parameters can be applied. Whenever a project analyst estimates the adoption rate, the pricing of important inputs or the yield enhancing effects over a couple of years, he/she will report a single value, although he/she knows very well, that it really is the mean of an imputed distribution of possible values.

The methods of formal risk analysis enable us to make the underlying distribution transparent and to include the augmented information into project evaluation. A simple distribution, which depends only on three bits of information is the triangular distribution function. It is defined by a minimum *a* and maximum *b* and the mode *m*, which represents the most probable value. Figure 11 gives the probability density function of a triangular distribution with the parameter values *a*, *b* and *m*. For many experts, it will not be too difficult to give estimates for the lowest and highest value of the parameter as well as the most probable value. The triangular distribution is determined by these parameters and can be used in stochastic simulation procedures.

Figure 11: Probability density function of a triangular distribution



Source: own presentation

Algebraically, the probability density function is defined section-wise by

$$f(x) = 2\frac{(x-a)}{(b-a)(m-a)}, \quad x \le m$$
$$f(x) = 2\frac{(b-x)}{(b-a)(b-m)}, \quad x > m \tag{4.1}$$

and the cumulative distribution function is given by

$$F(x) = \frac{(x-a)^2}{(b-a)(m-a)}, \quad x \le m$$
$$F(x) = 1 - \frac{(b-x)^2}{(b-a)(b-m)}, \quad x > m. \tag{4.2}$$

The striking simplicity of this method suggests its use to make the underlying assumptions of expert assessments transparent. The following parameters are often estimated by experts and should be included with their stochastic dimension:

- all long-term estimates (production increases, input savings)
- behavioral assumptions (adoption rate)
- market prices

A disadvantage of this simple approach is the inability of capturing the covariation among parameters in complex situations. This is not only attributable to the method itself but also to the limited cognitive capacity of assessors to account for covariation in a quantitative way.

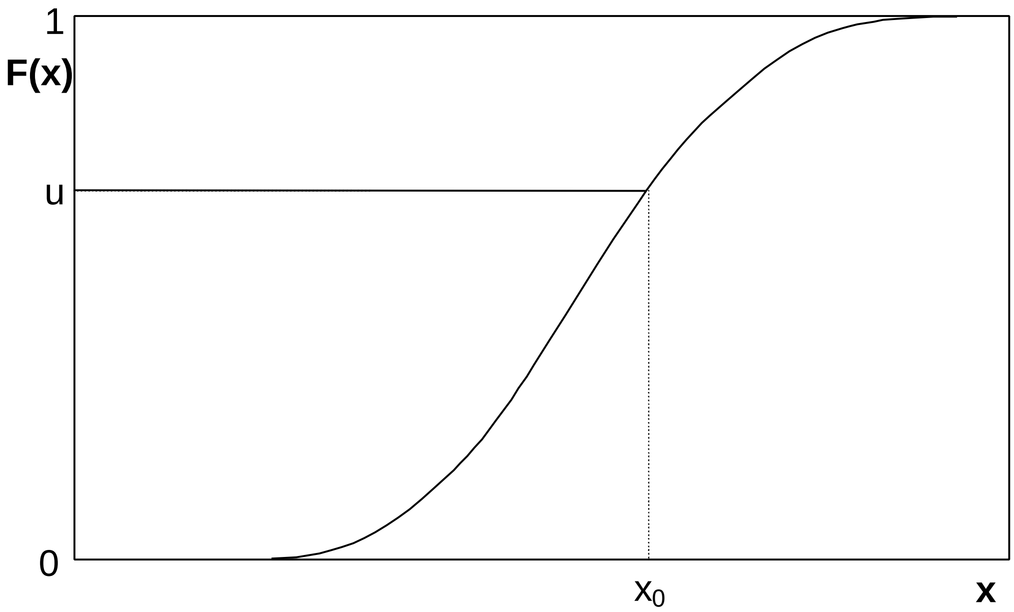
4.4 Monte-Carlo-Simulation and stochastic efficiency analysis

Monte-Carlo-Simulation offers a solution to the problem of integrating different risky variables into the calculation of summary criteria. It is proposed as a method to obtain the cumulative distribution functions for the project summary criteria like net present value or the internal rate of return (see section 2.2). The evaluation of the results is accomplished by the stochastic efficiency analysis presented at the end of this chapter.

Risky outcomes underlying a continuous distribution can be represented as a risk profile, which is simply the graph of the cumulative distribution function. An example is shown in Figure 12. The range of values that the stochastic variable x takes are shown on the horizontal axis, while the cumulative probability is shown on the vertical axis. The probability u that the stochastic variable has a value of x_0 or lower can easily be read from the figure.

Such a distribution can be obtained by stochastic simulation or initially by direct elicitation from a decision-maker (section 4.3). The Monte-Carlo sampling method is used for stochastic budgeting and simulation. It enables the analyst to calculate the distribution of summary variables that are composed of several stochastic variables. In the desert locust context, this may be helpful if a probability distribution of benefits, e.g. prevented losses is known and also the costs are stochastic. In this case the method can be used to calculate the probability distribution of the net present value.

Figure 12: Example of a cumulative distribution function



Source: own presentation

Monte-Carlo-Simulation works by iteration of a simple procedure. First, a random value *u* from a uniform distribution in the range from zero to one is sampled. This value is transformed by the inverse of the cumulative distribution function (CDF) of the stochastic variable in question, x_0, which corresponds to *u* in Figure 14. The repetition of this step will re-create the underlying distribution. In each iteration, the procedure is done for all stochastic variables and the summary variable is calculated. After a sufficient number of iterations (i.e. 100 - 1,000), the distribution of the summary variable is obtained. Note that the simple procedure described here is applicable only for independent variables (HARDAKER et al., 1997). Stochastic simulation can be accomplished using standard spread sheet software like Microsoft Excel. Furthermore, special add-ins are available for spread sheet software, e.g. @Risk by Palisade Corp., which simplify the use of Monte-Carlo-Simulation for project evaluation. They provide facilities for the consideration of distributions as well as deterministic values, depending on the nature of the parameter, in every spreadsheet cell. They also provide a number of helpful features for running simulations and presenting the resultant probability distributions. Additionally, they are capable of using discrete distributions as well as considering the covariance among stochastic input variables.

Stochastic efficiency analysis

Once CDFs of different strategies are available, the selection of efficient strategies can be accomplished even without exact knowledge of the decision-maker's utility function. Stochastic dominance is used as selection criterion under the assumption that direct utility maximization applies. With increasingly specific assumptions on the utility function, more discriminating rules will identify progressively smaller sets of efficient strategies. An advantage of this approach is that the solution holds for all decision-makers whose utility function suffices the respective assumptions (PANNELL, 1991).

First-degree stochastic dominance (FSD) applies for all decision-makers preferring more to less, i.e. with an upward sloping utility function. Expressed technically, strategy A dominates strategy B exactly, when $F_A(x) \leq F_B(x)$ for all values of x with at least one strict inequality, where $F_A(x)$ and $F_B(x)$ are the cumulative distribution functions of the net present values of the respective strategies.

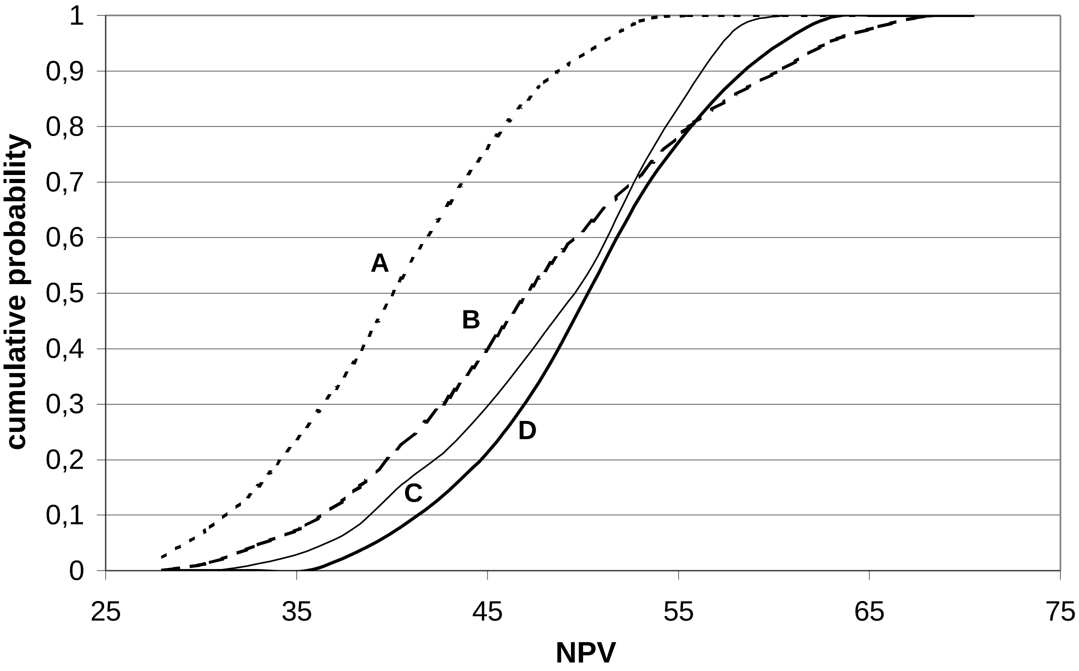
Second-degree stochastic dominance (SSD) is relevant for all decision-makers with an upward sloping utility function with decreasing slope, i.e. for risk averse decision-makers. Again strategy A dominates strategy B exactly when:

$$\int_{-\infty}^{x^*} F_A(x)dx \leq \int_{-\infty}^{x^*} F_B(x)dx$$

for all values of x^* with at least one strict inequality.

Third-degree stochastic dominance (TSD) is only rarely applied, because it depends on the demanding condition of a decreasing absolute coefficient of risk aversion while yielding only relatively small additional discriminative power over SSD (HARDAKER et al., 1997).

Figure 13: Hypothetical cumulative distribution functions of the net present value of four projects



Source: own presentation

Figure 13 shows the cumulative distribution functions for the net present values of four projects. It is obvious that strategy D dominates strategies A and C in the FSD sense. It also dominates B in the SSD sense, because the area enclosed between B and D left from the crossing point is clearly larger than that to the right of the crossing point.

A number of methods are available for a theoretically sound analysis of risky prospects. This is helpful, because risk averse decision-makers will deviate from a predicted choice that is based on expected values only.

The consideration of risk is needed for the analysis of desert locust policy options for two reasons. Firstly, farmers' reactions to public interventions cannot be fully captured without accounting for risk. A clear distinction between the risk attitudes and the degrees of belief in certain outcomes of individual decision-makers can be made. Therefore, it is possible to acquire information on uncertain outcomes from farmers. This is of particular importance, because for many problems no long-term time series data are available.

Secondly, those in charge of deciding on public investments in the desert locust case are confronted with uncertain outcomes. A formal analytical approach facilitates the decision under risk and can enhance the transparency of the decision process. Therefore, the analytical framework proposed in chapter 3 includes necessary information on the probability distribution of benefits and costs. Thus a decision can be made consistent with the risk attitudes and economic rationality.

5 A hypothetical example - Desert locust control in "Africaland"

After the analytical framework and the necessary methodology have been presented, an example shall demonstrate how the concept can be applied. Due to lack of real world data the case will rely on hypothetical data which are suitable for illustration purposes.

Suppose that the country “Africaland“ together with its neighboring countries has been supporting public control for about two decades. Historic evidence has shown that damage due to desert locust swarms invading farmers' fields could not be completely prevented. In the case of a desert locust attack, small-scale farmers were hit most seriously. After a recent desert locust invasion, the Chairman of the Desert Locust Control Board of Africaland (DLCBA) gets under pressure from farmers and consults his economic advisor for further action. See their discussion in the following.

Chairman: *Did you read the newspapers? The Africaland Peasant Association (APA) makes pressure to improve our desert locust management. They claim that our control strategy has failed and we should compensate the most seriously affected farmers. We must set-up an emergency program and concurrently improve and intensify our control efforts to prevent an invasion under all circumstances in the future. Unfortunately, I do not see how we can increase the available funds for desert locust control or for the compensation claims.*

Advisor: *I agree that we must do something about the issue. First of all, I think that giving in to compensation calls is very dangerous. Once the dam is broken, other groups affected by natural disasters would surely call for the same kind of cash injection. In my opinion, compensation is only viable when beneficiaries contribute to financing such a compensation scheme, which is the case for insurance contracts. In fact, for many developed countries there is agricultural insurance. For example, hail insurance covers crop losses from weather hazards. This is offered by the private sector.*

Chairman: *This is well known, but we don’t have insurance - and insurance cannot prevent crop loss. How shall we feed the population when desert locusts destroy our crops? To me, insurance does not seem to be a very attractive solution to the problem.*

Advisor: Take a l*ook at the statistics for the agricultural production of Africaland over the last 25 years. You can see that in the years with significant desert locust damage, our national production was always above average. Other factors like rain affect our national production more severely than desert locust damage.*

Chairman: *You are right, indeed. And this also sounds logical from a biological point of view. The humid years provide good conditions for our crops as well as for the development of big locust populations. I never thought about that. But anyway our problem remains: How can we secure the food supply for those who are actually affected? You should know that desert locusts destroy sometimes all the fields of a farmer. Huge swarms attack whole villages and often entire districts. Even several provinces were affected in one year.*

Advisor: *Well, this is exactly where insurance is beneficial. In principle, the indemnities are paid only to those farmers who are actually affected. The indemnity gives them the opportunity to buy food and inputs to continue their enterprise. The supply of food is managed by the network of wholesalers and retailers and will include some transport of foodstuff into the affected areas.*

Chairman: *Ok, I see the point. But before we can rely on such an insurance scheme, we should know whether this concept works. I have my doubts. How can we make sure that the proposition is viable?*

Advisor: *We should assess the performance of both, the insurance scheme and our present control program to identify the most efficient strategy. Let us go through the steps in detail. First, we need clearly stated objectives.*

Step 1: Specify objectives

Chairman: *That is easy, we just stick to our mission: We want to protect the small-scale farmers from the threat of desert locusts to their livelihood. Furthermore, the whole rural population shall be safe from food insecurities caused by desert locust attacks.*

Advisor: *Does this mean that large-scale commercial farms do not belong to the targeted group?*

Chairman: *Well, our primary target groups are the small farmers and the rural poor. Of course the bigger farms can benefit from an intervention of the government at the same time, but we think they could protect themselves or* *contribute to protection activities if they perceive the government's activities as insufficient.*

Step 2: Alternative strategies

Advisor: *Thank you for the clear statement. Let us proceed with the agenda. Although we are discussing already two alternative strategies, we still need some more details to carry out the evaluation of our supposed strategies. I would propose the following specifications:*

> **Public intervention strategy 1 (chemical control)** refers to continuing of the current public control regime. This includes a continued funding of the survey and control activities including reinvestment in the related equipment. Table 24 lists the effects of this strategy in more detail.

As the Plant Protection Department was quite successful with introducing the IPM concepts aimed at capacity building among the farming community, I could imagine an insurance system run by the farmers themselves. I would propose a pilot study as follows:

> **Public intervention strategy 2 (insurance):** A project that aims at establishing a cooperative insurance system against the desert locust risk in a few villages shall be used to explore the viability of this approach. Beginning with a period of participatory training, farmer networks on the village level shall be established and progressively institutionalized as cooperative insurance providers. External funding is necessary in the start-up phase, while the running costs must be covered by premium payments. The insurance offers coverage of 80% of the damage by desert locust invasions on the supposition that farmers help minimizing the damage, e.g. by re-sowing or replanting if possible. Indemnities are paid on the basis of field inspections, which will be used for determining the extent and cause of damage. The insurance contract covers 80% of the difference between the yield that would have been harvested without the invasion and the fraction the farmer still can attain on this field during the season. Premiums consist of the actuarial premium and DCU 60 per hectare for covering the administration costs. The actuarial or fair premium is the amount that is repaid to the insurance taker on average. It depends on the risk settings and will be calculated for small areas separately. See Table 24 for the effects expected from this strategy.

Table 24: Expected effects of alternative intervention strategies

Chemical control	Insurance system
reduced probability of desert locust damage (crops, pasture, fodder)	no effect on desert locust damage
farmers' adaptation	farmers' adaptation
slight effect on farm-household income variation	reduced variation in farm and village household incomes
investment costs (reinvestment for monitoring and spraying equipment, storage facilities etc.)	investment costs (establishing infrastructure)
operation costs (fuel and pesticides, seasonal labor, maintenance of equipment, disposal costs)	operation/transaction costs (contract acquisition and monitoring, indemnity payments, reinsurance)
health costs (spraying staff, bystanders, consumers through contaminated food)	no health costs
environmental costs (contamination of water and soil with pesticides, stability and biodiversity of ecosystems)	no environmental costs
production loss (loss of bees and other beneficial arthropods, loss and reduced fecundity of livestock)	no production loss

Source: own presentation

Chairman: *I am ok with these formulations. Evaluating strategy 1 is no problem as we have a lot of experience but I would like to have strategy 2 assessed in a small scale project first.*

Step 3: Reference system

Advisor: *Yes, I agree for the project size. But I am not sure whether the existing experience with the control strategy is of great help in the economic analysis. Before quantifying and valuing the benefit and cost components of the alternatives let us clearly define the reference system. For comparing our strategies, it is most convenient to measure both separately against a scenario of no public intervention. In such a scenario, farmers are expected to adapt to the natural desert locust risk by following local compensation and adjustment strategies. Adaptation will also occur in any other scenario that affects the risky environment of the farm.*

Chairman: *Well, this sounds strange to me. Why should we not choose the current strategy as a reference system? After all, it is the starting point from which our decision will be made.*

Advisor: *We have to analyze both strategies, insurance and control, if we consider them as alternatives. We can later compare their economic performance if the evaluation is based on a common reference scenario. If we wanted to consider insurance as a supplementary intervention, we would take the control scenario as a reference.*

Chairman: *Ok. For the time being, we cannot afford any expenditure beyond our control budget. So let us explore the options as alternative interventions for now. You can start data collection right next month.*

Step 4: Farm level analysis

Chairman: *Welcome back from your trip! Have you been successful? I am really curious to know what you found out.*

Advisor: *I think I got a lot of useful information. Although the database is still limited, we can make some preliminary exploration. I did my surveys in the Sambari region, which is particularly suitable for our purposes, because it is sufficiently homogenous with regard to agro-ecological conditions. At the same time, the southern districts were more or less subject to the natural desert locust risk, because the tribal leaders have stopped all survey and control operations in those areas.*

Chairman: *Oh, I know these stubborn tribes. I guess their resistance is responsible for some of the outbreaks of the recent years. Our government should not let them get away with their illegal interference. Anyway, what were your findings?*

Advisor: *I will limit my explanation to a single crop for the moment. Look at Table 25. I set up the crop budgets for the northern districts, where our control campaigns are well implemented (column A) and for the southern districts, where the locust risk is rather left to nature's conduct (column B).*

Chairman: *I see. But why are the farmers in the southern districts so inefficient? For growing the same crop they are getting so much less revenue compared to their colleagues in the north, even if the off-farm income is added?*

Table 25: Crop budgets and composition of farm-household incomes in different desert locust management regimes

	northern districts	southern districts	southern districts	insurance project area	
	public intervention*	**no public intervention**	**hypothetical: no adaptation**	**with insurance**	
	A	**B**	**C**	**D**	**unit**
yield (100%)	3,000	1,900	3,000	3,200	kg/ha
base price	2.5	2.5	2.5	2.5	DCU/kg
revenue	7,500	4,750	7,500	8,000	DCU/ha
seed	20	20	20	20	DCU/ha
fertilizer	400	400	400	500	DCU/ha
pesticides	100	100	100	100	DCU/ha
animal traction	150	150	150	150	DCU/ha
family labor	500	300	500	500	DCU/ha
hired labor	500	750	500	500	DCU/ha
land	800	800	800	800	DCU/ha
insurance premium				2,582	DCU/ha
transportation	120	80	120	120	DCU/ha
Total costs	2,590	2,600	2,590	5,272	DCU/ha
net revenue	4,910	2,150	4,910	2,728	DCU/ha
farm size	5	5	5	5	ha
off-farm income		1,800	0		DCU
“deterministic” income	-2,470	-720	-2,470	1,248	DCU/ha
risky income	7,380	4,670	7,380	1,480	DCU/ha

A: the government intervenes with public control.
B: no public intervention but farmers self-insure.
C: No public control, hypothetical scenario without self-insurance,
D: no public control, but market insurance.

Source: Hypothetical data

Advisor: *Many farmers in the South grow the crop extensively to be able to work abroad. That gives them a certain income, even if desert locusts destroy their crop. What is inefficient from a society’s point of view, is rational from the individual farmer’s point of view. This will become clearer if we take a closer look at the risk dimension. As you can see in Table 25, I summarized the items in the crop budget that are independent of the desert locust situation. I called this the deterministic portion of the income, which is mainly the sum of the cost items.*

Chairman: *And the yield on the other hand is the outstanding stochastic or risky component. What does this 100% in the yield row mean?*

Advisor: *Well, the yield level determines the gross revenue earned by the farmer. This and the marketing cost make up the risky income component. The 100% signify that this is the average yield level that can be attained in the long run in the absence of desert locust damage.*

Chairman: *But what does this tell us? We knew all that before.*

Advisor: *I also investigated the farmers' perceptions of risk. I asked them to think about their experience of desert locust damage in the past. Also I wanted to know what expectations they have on the overall loss in terms of produce to sell or consume under the presupposition that they would apply all available mitigation efforts like replanting. From their revealed expectations I made tables like the one given in Table 26 and asked them to arrange a number of pebbles according to the degree of belief that these states of nature come true. I then calculated the individual probabilities. By the way this is known as the visual impact method.*

Table 27 gives the aggregated results for the samples in the northern and southern districts.

Table 26: Visual impact tableau

State of nature	Counters	Count	Probability
no desert locust damage	●●●●●●●●●●●●●●	14	14/20 = 0.7
light damage (-20%)	●●●●	4	4/20 = 0.2
severe damage (-40%)	●	1	1/20 = 0.05
catastrophic damage (-80%)	●	1	1/20 = 0.05
Total		20	1.00

Source: own presentation

Table 27: Discrete probability distribution of yield loss percentage obtained from visual impact survey

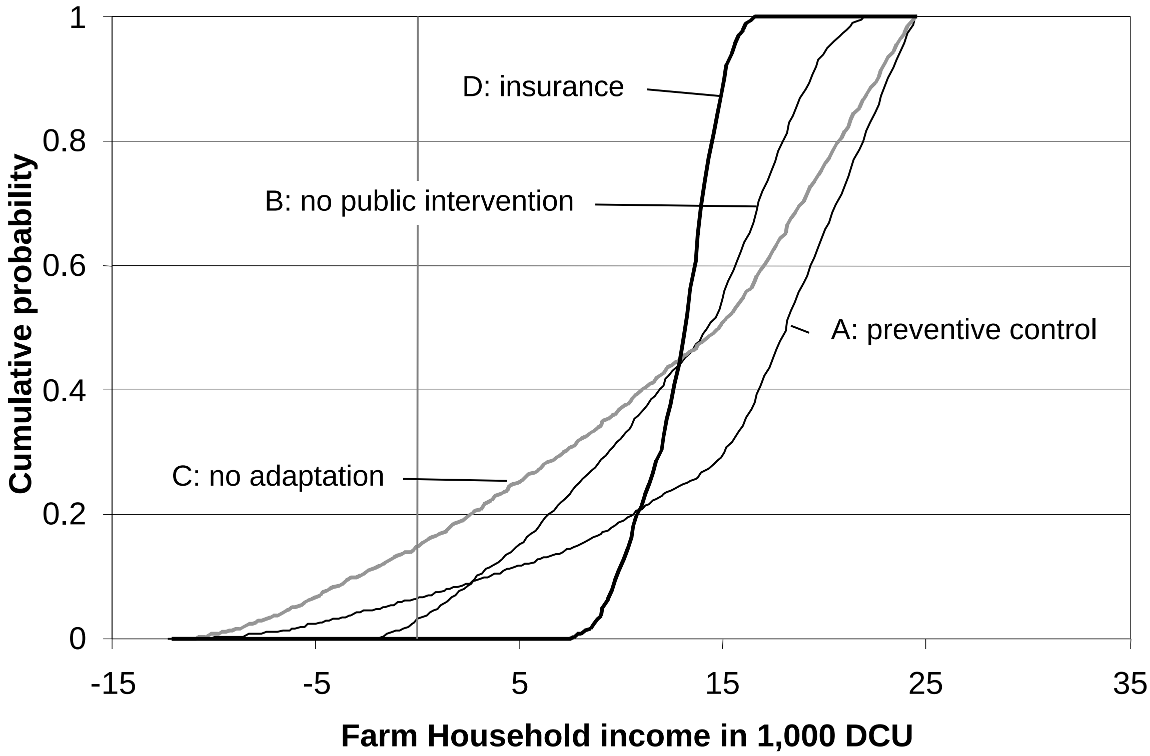
	northern districts (public control)		southern districts (no public control)	
yield level	**probability**	**cumulative probability**	**probability**	**cumulative probability**
0%	0.00	0.00	0.00	0.00
10%	0.01	0.01	0.04	0.04
30%	0.06	0.07	0.12	0.16
50%	0.08	0.15	0.16	0.32
70%	0.15	0.30	0.20	0.52
90%	0.58	0.88	0.40	0.92
100%	0.12	1.00	0.08	1.00

Source: own calculations

Chairman: *I never would have thought that farmers have an idea of these probabilities. I am not sure whether we can rely on this kind of data.*

Advisor: *Well, farmers are experts of their business and many of them have a long experience. So they also have a sufficient knowledge about the local risk of desert locust invasions. With these probabilities, I ran a stochastic simulation. That is simply calculating the budget shown in Table 25 many times with different levels of yield taken from Table 27 and considering the respective probabilities. This is done in a way that recreates the distribution given by the probabilities we obtained from the farmers. We get a probability distribution of the farm incomes. This method is called Monte Carlo Simulation (section 4.4). We can represent the obtained distributions as a graph of their cumulative distribution functions. This results in the curves A and B in Figure 14*.

Figure 14: Cumulative distribution functions for farm-household income in different policy scenarios



Source: own calculations

Chairman: *I see. Looking at the figure (Figure 14), I recognize that curve A lies to the right from curve B most of the time. This means that farmers in the districts with effective control can attain higher incomes than those in the southern districts with a high probability.*

Advisor: *Yes that is the point. Only with a very low probability, the incomes in the northern districts are lower. Unfortunately, for this constellation, there is no clear rule to decide which of these strategies is preferable, since we do not exactly know the risk preferences of the farmers. For other cases, we have the so-called stochastic dominance criteria. The criterion of first-degree stochastic dominance relates to all decision-makers who prefer having more income to having less. See curves A and C for an example. Curve A lies exclusively to the right of curve C and hence dominates C according to first-degree stochastic dominance.*

Chairman: *That means that compared to strategy C, our public control strategy (A) is preferable for all farmers. That is what I expected. By the way, what is strategy C about? We only discussed A and B so far.*

Advisor: *Let me tell you about strategy C. Strategy C is a hypothetical variation of strategy B, which I observed in the southern districts. I just wanted to see what happens if farmers in the southern regions refrain from earning a part of their income abroad. You can see in Table 25 that I left out the off-farm income for strategy C in the budget. I assumed that farmers in this case run an intensive cropping pattern like in the northern districts. In other words, this is a strategy without self-insurance in the high-risk area.*

Chairman: *So, farmers in the southern districts can choose among strategies B and C in principle? And because C has a higher variation as the comparison of the curves shows, they tend to prefer B?*

Advisor: *Yes, farmers can choose to earn off-farm income as a kind of self-insurance. But this comes at the cost of a lower total income. The other choice is not to insure, i.e. not to work abroad but getting a higher average income. But it is not only the higher variation in strategy C that makes it less preferable. For risk averse decision-makers, we can apply the criterion of second-degree stochastic dominance. According to second-degree stochastic dominance, strategy B dominates C, because the area enclosed by the curves below the crossing point is larger than that right of the crossing point. That is why farmers self-insure in spite of the cost.*

Chairman: *So most of the farmers will engage in some kind of self-insurance activities, I guess. But what about strategy D. If I grasped the criterion of second-degree stochastic dominance correctly, D dominates B and C, because the enclosed areas below the crossing points are bigger than those above. So farmers should adopt strategy D if they are located in the southern areas where the desert locust risk is high. Why would farmers apply strategy C if D is better?*

Advisor: *Because they cannot get market insurance, yet. Strategy D represents our insurance project. Or rather what I expect it to be because it is still more or less hypothetical. Have a look at Table 25 where I put the crop budget for this strategy. I determined the actuarial premium for the insurance by calculating the expected losses from Table 27. 80% of this expected loss will be repaid to the insurance taker on average. The amount of DCU 2522 per ha represents the actuarial premium. Together with the administration cost of DCU 60 per ha, this makes up the insurance premium that is listed as a cost in* *the farmer's budget. I assumed that the farmer could afford to intensify crop production, because she/he is effectively insured. She or he is willing to buy more inputs, here fertilizer, and increase the potential output.*

Chairman: *But this is still your assumption. And strategy D is the most efficient for the southern districts, where the locust risk is higher. But overall, public control is the best strategy. These are the results of your findings, I guess.*

Advisor: *Well that is only partially right. D is the most efficient strategy with respect to second-degree stochastic dominance compared to B and C. But in comparison with A we cannot judge with our stochastic dominance criteria, because the curves cross and the area below the crossing point is smaller than the one above. Furthermore, we must advance to the project level if we want to judge public control in comparison to insurance. The operation costs of insurance were included in the premium and hence are accounted for in the farm level analysis. But the costs of public control have not been considered at all. So let us see what additional information we get on the project level.*

Step 5: Project level analysis

Chairman: *Ok, for the project level we just have to aggregate the individual farm data. Then the direct costs of the project must be included. Let me see what you have found out*.

Advisor: *This is most important if one goes from farm level to project level analysis. But there is still more to it. On the one hand we have to consider that taxes or subsidies, import or export duties and market imperfections make the market prices deviate from the so-called efficiency prices or shadow prices. While we must use market prices for farm level analysis, the project level analysis needs the valuation of project inputs and outputs with efficiency prices. Furthermore, we must deduct transfer payments from the benefit and cost components.*

Chairman: *Can you explain why we need two different prices for the same good?*

Advisor: *Well, within a cost-benefit analysis, we want to measure the project's contribution to net social income to provide a yardstick for the comparison of different projects. Transfer payments do not increase the social income but take it from one person and give it to another. The same holds true for taxes* *and subsidies, except that they affect the government's cash balance. The shadow price represents the true scarcity of a resource or its opportunity cost.*

Chairman: *What again is this opportunity cost?*

Advisor: *That is the cost of foregone production if we take a resource from an alternative use and utilize it in our project. But I don't want to make it more complicated than necessary for the moment. As we have no policy that heavily distorts the agricultural markets, I only took a different cost for family labor, which is frequently overvalued. I got a figure that is 20% less than the one used in the farm level analysis from the planning department*.

Chairman: *Ok, but now we must go into the details of the project size and aggregate the farm level data.*

Advisor: *Sorry, but I still have to make another comment. We have to consider the market effects as well. As you will know, supply and demand determine a market price. Our projects now have different effects on the market supply, because public control can reduce the crop loss, while insurance cannot. This means the market price may rise if we decide to change our public intervention strategy. The extent of such a price rise is largely determined by the elasticity of demand and the elasticity of supply. In the short run, the local supply will be quite inelastic, meaning that a price increase will not lead to an increased market supply.*

Chairman: *That is obviously due to the fact that farmers need time to adapt their production. They cannot sell more than they have produced in that season.*

Advisor: *That's right. But there are also buffer stocks and there is trade in foodstuffs among regions. This trade is much more elastic, because traders will sell their produce where they can get the best prices. In addition, there is the elasticity of demand as a second factor to determine the extent of a price rise. For the moment let us assume that the overall supply elasticity is high due to existing trade. Then the price increase resulting from local production shortfalls is insignificant. As a consequence, only the producers bear the economic impact of a desert locust invasion.*

Chairman: *But now show me the results of your findings.*

Advisor: *Let us take the alternative projects one by one. To make them comparable I took an area of 5,000 hectares, which covers the land of about 1,000 farmers, for each project. Let me start with public control. In Table 28, I summarized the annual benefits and costs of this strategy on the project level.*

Chairman: *Let me see. So you took the difference between household incomes from strategies A and B as a benefit of public control. Is that everything? Don't you account for the saved crop losses?*

Table 28: Benefits and costs of public control (5,000 ha area, in DCU 1,000)

Benefits	Household incomes under strategy B	10,550
	Household incomes under strategy A	13,941
	Additional household income	3,391
Costs	Annual project costs	750
	Production losses in livestock	360
	Health costs	300
	Environmental costs	?
	Total costs	1,410

Source: own calculations

Advisor: *The reduced damage probabilities are already included in these figures, because I calculated the expected household incomes with respect to the given damage probabilities. From the farm level analysis, we know that if there is no public control (strategy A), farmers will stick to strategy B. So the effect attributable to public control is in principle the difference in household incomes between these two strategies.*

Chairman: *Ok, I agree with you on the benefit estimate. Let me see the cost side now. The annual project cost of DCU 750,000 is an allowance for the running cost of survey and control activities including pesticides, I guess. That seems a bit too high for an acreage of 5,000 ha. And where did you get these figures for livestock loss and health costs?*

Advisor: *I took the operation costs from our own records, so that is safe. But I made an allowance for reinvestment, which is necessary over the ten-year project period. The figure for the losses in livestock production stem from a small survey I conducted among pastoralists in the northern districts. They were asked for the incidence of perished animals and the causes. On average, nearly 20% of the cases were attributed to intoxication after aerial spraying. But I must say, that the usual incidence is much lower, because these figures include one major accident where nearly 80 sheep died. I crosschecked the figures with the extension service. They were of the opinion that at a maximum 10% of the perished livestock could be attributed to locust pesticides. But at* *the same time they also pointed out that a reduced fecundity may be a consequence of low level intoxication. So I took 15% as a mean and valued the lost livestock at market prices.*

Chairman: *These folks play politics all the time. They don't like us because we sometimes spray their pastures and that is why they give these exorbitant figures.*

Advisor: *But there must be a reason for them to dislike the pesticide sprays. Consider the tribal leaders in the south. There, too, must be a reason for making such an effort in keeping us out of their territory. I think we can stick to the estimated DCU 360,000, because I did not even consider all components, like e.g. the loss of bees. But let's more on to the figure for health costs. This is a crude estimate, which I obtained by taking 200% of the pesticide costs for the health cost. This is a value that was obtained for rice production in the Philippines (ROLA and PINGALI, 1993). I know that this is a weak substitution for a real figure, but I think it is important to include some estimate when there is not yet better evidence. Alternatively we could have taken the labor hours of the applicators of the DLCBA which were lost due to health problems related to intoxication.*

Chairman: *That is tough. I am not sure if that crude estimate is acceptable. You know we equip our staff with protective gear of high quality. I don't see where and why these health costs should occur.*

Advisor: *You know that there are reports on occupational health hazards among our staff. In addition, the cholinesterase level checking is supervised only very loosely. But also bystanders like the pastoralists get contaminated from time to time. I want this health cost to be included in the calculation.*

Chairman: *Ok, let's leave that topic and see the results.*

Advisor: *To be realistic, I set up a project plan for a ten-year period in Table 29. We can be sure that all farmers in the project area benefit from public control. In year zero, the necessary infrastructure must be established. That means buildings, aircrafts, vehicles and facilities. In the first year, when the service is operational, the storage facilities must be equipped and filled and a first investment in the operational material is necessary. These items make up for the investment costs in the first years. For the following years, I only put the annual costs and benefits as identified in Table 28. Calculating the summary criteria for this project with average values, yields a net present value of DCU 3.2 million when discounted at 15% interest rate and an IRR of 28%.*

Table 29: Investment plan for public control (in DCU 1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Adoption	0	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Costs											
Investment	5,000	2,000									
Annual costs		1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410
Benefits		3,391	3,391	3,391	3,391	3,391	3,391	3,391	3,391	3,391	3,391
Net benefit stream	-5,000	-19	1,981	1,981	1,981	1,981	1,981	1,981	1,981	1,981	1,981
Discounted stream	-5,000	-16	1,498	1,303	1,133	985	857	745	648	563	490

NPV: 3.2 Million at discount rate of 15%, IRR: 28%
Source: own calculations

Chairman: *Those are quite impressive figures. I think we can be proud of these achievements. Now I want to know if you can attain such profits also with an insurance project.*

Advisor: *With insurance, there are some difficulties when we want to ascertain the benefits. As we intended, the primary beneficiaries of insurance are the farmers. As the discussion in section 3.4 has revealed, the benefit of insurance depends on the risk preferences of farmers. For this reason, I used the contingent valuation method (CVM) to measure the worth of insurance.*

Chairman: *What is the contingent valuation method? How does it work?*

Advisor: *The contingent valuation method is mostly applied in environmental economics. It is used to obtain values for non-marketed goods, mostly environmental goods. It is carried out as a survey and tries to set up a hypothetical market for a clearly specified product. Then the respondent is asked to reveal her or his maximum willingness to pay for this product. In my specific case, I asked for the willingness to pay for insurance for desert locust losses*.

Chairman: *But people can give you any number in such a survey. Or are you going to collect the money?*

Advisor: *It is of course very important to give a clear reason for the payment and to make the market setting as realistic as possible by stating a mode of payment. Here is the hypothetical market question that I asked them: "The government of Africaland considers to abandon public locust control and wants* *to establish an insurance system instead, to cover the risk of desert locust damage the farmers in Africaland face. This insurance shall be organized by local farmer associations, which will be built up by means of a development project. However, for the functioning of insurance, it is a prerequisite that the beneficiaries contribute to cover the costs by regular premium payments.*

If you were offered an insurance that covers 80% of all losses caused by desert locusts invading your fields, what would you be willing to pay annually for this service?"

Chairman: *And you got answers to this question?*

Advisor: *You know, I traveled to the southern districts, where a more or less natural desert locust risk prevails, because we want the projects "insurance" and "public control" as alternatives. Farmers were very cooperative. I think that's an indication of their appreciation for the insurance project. After all, that is their chance of getting help for damage from desert locusts. I calculated also an average willingness to pay per hectare, on the basis of the general socio-economic data I gathered along with the individual willingness to pay. It is always useful to do that in order to see if the survey results appear to be consistent. I calculated an average willingness to pay for insurance with 80% coverage of about DCU 3,000 per ha. That is quite an amount. When grossed up to the project size of 5,000 ha, that makes a willingness to pay of DCU 15 million annually.*

Chairman: *To me that seems very high. Do you think that is realistic?*

Advisor: *I think that is realistic. We have a significantly higher risk of damage in the southern region and I also calculated an average loss of about DCU 2,520 per ha. Note that this is the actuarial premium, the part that is on average repaid to the farmer by the indemnities. So that makes up a great part of the willingness to pay. The worth of insurance is only the excess willingness to pay over the actuarial premium. We account for this as a transfer payment in the cost-benefit analysis. The sum of DCU 15 million for an annual willingness to pay for insurance on the project level may seem high, but about two thirds go back as indemnities to the farmers – at least in the long run and on average.*

Chairman: *Ok, but now the costs.*

Advisor: *The annual costs of the project are mainly the administration costs of the insurance operation, which shall be covered by the insurance premiums. I assumed that DCU 60 per ha would be sufficient. See Table 30 for an* *overview of annual benefits and costs. Besides the annual costs, there are cash outlays for establishing the farmer networks and the facilities.*

Table 30: Stream of annual benefits and costs of the insurance project (at 100% adoption).

benefits	**in DCU 1000**
willingness to pay	15,000
- actuarial premiums	12,608
= annual benefits	**2,392**
costs	
Administration costs (at DCU 60 per ha)	300
production losses in pastures	-
health costs	-
environmental costs	-
sum	**300**

Source: own calculations

Chairman: *I assume that you put those costs in the row "investment cost" of the investment plan in Table 31.*

Advisor*: Yes, that's right, The direct project costs are mostly for initiating the village networks. First, an initial number of villagers has to be trained. Also the set-up of the network and the facilities will cause costs before the insurance is operational. I assumed DCU 3 million in year zero. 40% of farmers shall adopt insurance in the first year. Then, each year, an additional 20% and later 10% of farmers shall be trained and included in the scheme. For the training of farmers and the extension of the service I made some allowance in the investment cost row.*

Chairman: *I see. The operation cost are then the costs for administration purposes and are covered by the extra DCU 60 per ha the farmer would have to pay. But why are they considered here among the costs? The farmer will pay them, so that it is not a project cost.*

Advisor: *Well, we must account for all the resources the project uses. These DCU 60 per ha are used e.g. for covering the fees of the insurance staff. As a consequence, this figure reflects the project's use of labor. Therefore, we put this in the cost category. Remember the concept of opportunity cost.*

Table 31: Project account for a 10 year period of market insurance (in DCU 1,000)

year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
adoption	0	40%	60%	80%	90%	98%	98%	98%	98%	98%	98%
investment cost	3,000	1,000	1,000	500	500						
operation cost		120	180	240	270	294	294	294	294	294	294
benefits		957	1,435	1,914	2,153	2,344	2,344	2,344	2,344	2,344	2,344
net benefit stream	-3,000	-163	255	1,174	1,383	2,050	2,050	2,050	2,050	2,050	2,050
discounted net benefits	-3,000	-142	193	772	791	1,019	886	771	670	583	507

Source: own calculations

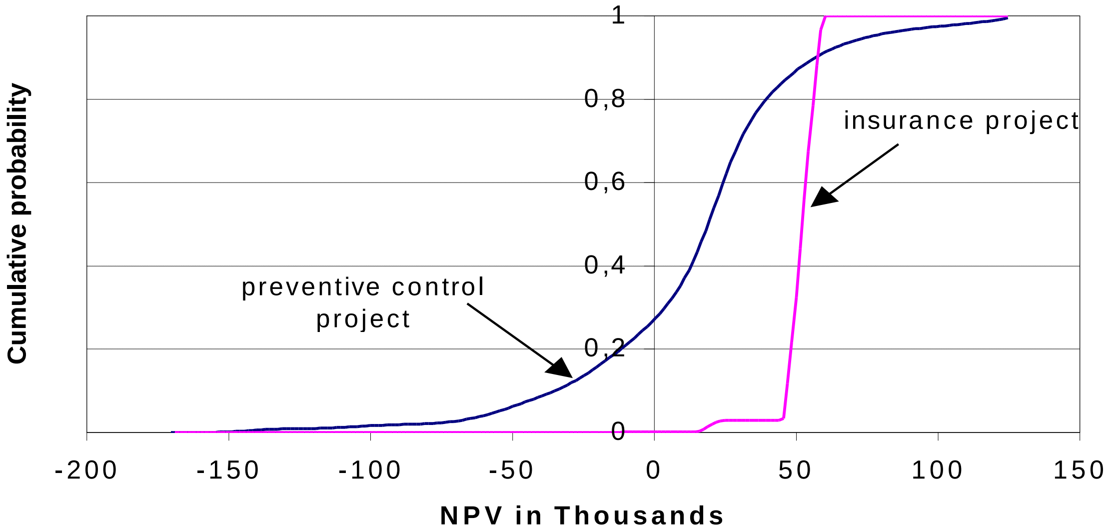
Chairman: *But what is the project's overall performance now?*

Advisor: *At a discount rate of 15%, the NPV (net present value) is about DCU 3 million and the internal rate of return is 30%. That is comparable to the public control project.*

Chairman: *I am astonished, that this is possible. But what about the risk dimension. We have had the risk considerations on the farm level, but now we have lost this information, as it seems to me.*

Advisor: *That's a good point. I left out the risk considerations to clarify the principles of establishing the project account. But we can – as we did on the farm level – add the information we have on risk into our project account. I did this again by using the Monte-Carlo-Simulation. Instead of the single estimate for the benefits of public control, I put the difference of the yields of strategy A against those of strategy B a few thousand times, each time sampling them from the probability distribution in Table 27. I got a new probability distribution for the yields saved by control campaigns. That is what makes up the benefits* *of this strategy. Look at the sigmoid curve in Figure 15. It represents the cumulative distribution function of the NPV of public control.*

Figure 15: Cumulative distribution functions for net present values of the public control project and the market insurance project



Source: own calculations

Chairman: *I see. And the cumulative distribution of the NPV of insurance is much narrower. That means, it is overall less risky than the public control strategy?*

Advisor: *In a way, yes. But the easiest way of deciding which is the most efficient strategy is again applying stochastic dominance criteria.*

Chairman: *Then insurance dominates public control according to second-degree stochastic dominance...*

Advisor: *...which means, it is the preferable strategy for all risk averse decision-makers.*

Chairman: *Well, that means we have to consider insurance as a competitive strategy. Let us see what the council members think of this idea. We should at least start a pilot project. However, if we scale up this approach, and reduce our control efforts, we might get into trouble with our neighbors.*

Advisor: *Yes, the international issue has to be considered when we think of alternative intervention options. But the considered strategies are not mutually exclusive. We might combine both strategies, i.e. protect the small-scale* *farmers better with insurance and still do survey and control to avoid swarms developing on our territory.*

Chairman: *Yes, but that is still a long way off. For now, we should start with the pilot project …*

Due to the attempt of giving a clear example, only a part of the concepts proposed for an in-depth analysis of desert locust management interventions could be demonstrated. An extension of the example should in the first place include the evaluation of the environmental costs. Moreover, a consideration of other sources of yield risk and the covariance of yield fluctuations and desert locust damage should be constituent components of a sound analysis. These points were left out for the sake of brevity in the “Africaland” example. Far from being a real world application, the example, however, shows the principal procedures as well as the main lines of reasoning behind the analytical framework, and contributes in this way to the objective of this booklet.

6 Salient points of economic analysis of desert locust management

The preceding chapters introduced a comprehensive framework for an economic evaluation of desert locust management strategies. It is hoped that the framework contributes to rational decision-making on a transparent basis based on unambiguous evidence of the effects of public intervention strategies. To achieve this goal, some particular characteristics of desert locust management have to be considered, which are easily overlooked and have been largely ignored in the past. The following statements summarize the salient points of an economic approach to analyze desert locust management:

1. From loss estimates to economic evaluation

   The debate on desert locust control was often dominated by the notion that desert locusts are the source of intolerable losses as such, with all consequences of conveying negative connotations by using of a "language of loss". On the contrary, from an economic point of view, damage costs and mitigation costs should not be treated as fundamentally different. Ideally, an economic evaluation is capable of identifying the optimal level of damage mitigation efforts by rationalizing the trade-off between these two cost components. As this point is a source of frequent misunderstanding between crop protection specialists and economists, a detailed discussion was given in section 3.3.

   Cost-benefit analysis provides a framework for comparing benefits and costs of public intervention projects in a transparent way. Therefore, the role of economic evaluation should be emphasized as a basis for rational decision-making. The tradition of simply citing figures of potential loss should be abandoned in favor of judging intervention strategies on the basis of economic performance indicators.

2. The role of the farmer

   The widely prevailing approach of measuring the efficacy in terms of desert locust control of physical yield prevented control operations fails to account for the true on-farm effects. While farmers and the rural population have been mentioned as important beneficiaries of public control, their own coping strategies were largely ignored. The benefits they received and the incurred costs resulting from public control measures were never investigated in detail. The omission of on-farm adaptation to desert locust risk leads to an overestimation of the benefits of control interventions.

The framework presented here takes the on-farm effects into consideration by relying on actual farm data. Accounting for the mitigation and coping strategies of farmers will yield more realistic results than an analysis that simply ignores them. This goes along with moving from yield to income as a principal indicator. This is also consistent with the findings that food insecurity is often caused by a lack of access to food rather than by insufficient food production. As a consequence, a modeling approach that relies exclusively on biological and technical relationships is rejected. Instead, data collection must concentrate on the strategies applied by farmers and their respective results.

3. The prominent role of risk

Although, risk played an implicit role in the discussion of desert locust control, the repercussions of risk on the farm level have not yet been considered in particular. Likewise, the formal and uncompromising integration of risk considerations in project analysis has not been pursued in spite of the prominent role of risk in desert locust management.

Therefore, the inclusion of data on the probability distribution of key stochastic parameters is pursued throughout the procedure presented in this booklet. The farm income in particular and the welfare implications of fluctuating market supply are the key stochastic parameters. In addition, estimates of direct project costs and external cost components as well as adoption rates should be included in the form of probability distribution functions. This can be easily included in stochastic simulation of summary criteria. Decisions based on an augmented database are likely to be superior and more easily acceptable.

4. The importance of external effects

In the past, external effects of pesticide use in desert locust control have not been considered in economic evaluation, although there is growing anecdotal and scientific evidence on their importance. Cost-benefit analysis evaluates projects from a social point of view, which requires the inclusion of all costs.

As a consequence, the incorporation of external effects is considered a constituent component of economic evaluation of desert locust management interventions. There are still difficulties in identifying and quantifying external effects due to the of lack of market prices. As competing strategies presumably differ in the extent of external costs, it is important to make an effort to evaluate these strategies with respect to their external effects. The methodology for the valuation of non-market goods has been presented. However, empirical research on the identification, quantification and valuation of the adverse effects of desert locust control is urgently needed.

5. The role of alternative intervention strategies

   From its beginning, public intervention in desert locust management has been dominated by control concepts. But when the scope is shifted from securing production to increasing and securing the welfare of farmers and other groups, alternative approaches, e.g. insurance schemes, should be considered too.

   To achieve a more efficient resource allocation and a higher level of food security it is a prerequisite to analyze a number of alternative projects. The development and implementation of desert locust management strategies should bring together a wide range of expertise viable and effective alternatives which are suitable for the specific socio-economic conditions in a given location.

This list of salient points highlights the most important issues of an economic evaluation approach of desert locust management strategies and emphasizes the methodological requirements.

It is assumed that appropriate sites for the comparison of different strategies can be identified. Previous approaches tried to avoid this problem by modeling the effects of intervention strategies. These models had to rely on a number of critical assumptions, whose effects could have easily changed the overall results of the analysis (e.g. the assumptions on control efficacy in the study of JOFFE, 1998). The approach presented here aims at capturing the effects of intervention strategies in a finer spatial resolution. It is proposed to use a case/control design, which entails the identification of appropriate sites. This allows the integration of farmers' adaptation and mitigation measures.

The basic idea is to find sites, where control campaigns have had only a negligible impact in the past, because desert locust control operations were not undertaken in neighboring areas. Particularly for breeding areas, this would represent a more or less natural risk of locust invasions. Certain areas in Yemen were mentioned to be suitable sites for a “no control” scenario (HASSAN, 1998).

A fruitful and smooth cooperation among plant protection specialists and economists is indispensable to identify suitable study sites in order to develop new and creative solutions to the “old” problem of the desert locust. While expertise in the field of plant protection provides the technical guidance, economic analysis should be understood as a helpful tool for improving the efficiency of intervention efforts. In addition, it helps directing the scarce and valuable development funds to a more efficient use.

Throughout the text several topics have been mentioned where research could significantly improve the knowledge on the socio-economic performance of locust management interventions. In-depth studies should be undertaken to elucidate the often alleged role of desert locust damage in causing food insecurities and to investigate the relationship and correlation between national production and desert locust damage. Case studies on the instruments farmers use to mitigate and cope with production shocks are helpful to discover to which extent farmers can manage the risk on their own and to evaluate the cost implications of such strategies. Against this background, the potential of different intervention strategies to mitigate the negative effects of desert locust damage can be evaluated on country, regional and global levels.

7 Summary

Desert locusts are known and feared as an important threat to crop production in the semi-arid areas extending from Western and Northern Africa over the Arab peninsula to Pakistan and India. Owing to their migratory activity, desert locusts are a border-crossing public “bad”, which made the governments of affected countries intervene with emergency control operations assisted by FAO and donors. In spite of considerable investments, economic evaluations of control campaigns are rather scarce. The most recent evaluation study makes use of a bio-economic simulation model developed from historical data and expert assessment to estimate the crop yield losses prevented by control operations. According to this study, desert locust control in African countries comes at a net loss of US$ 10-23.4 million annually, although external costs like health costs, production losses in livestock and environmental damage are not yet included in these figures. The approach of the study was heavily criticized and regardless of its results governments, international organizations and bilateral donors stick to a state-run control strategy.

This book aims at identifying economic concepts that are capable of integrating the most important dimensions of the desert locust problem in a more comprehensive way than previous approaches. A framework for the economic evaluation of desert locust management strategies is developed that captures especially the on-farm effects and the implications of risk in a more consistent way. It is expected that studies along these guidelines are more acceptable to the various stakeholders and can contribute more efficiently to an objective and transparent decision process.

As a first step, an illustrative example of the approach used in previous evaluation studies is presented. The shortcomings with regard to the stochastic nature of desert locust damage and farmers’ adaptation to the risky environment are discussed.

Chapter two elaborates on the main economic features of the phenomenon to be taken into account in an evaluation. On the one hand, the provision of desert locust control by the government makes it a free public good to the farmers in the affected area. Moreover, the migratory nature makes control an international public good to the affected countries. On the other hand, negative external effects of pesticide use are likely to affect e.g. livestock and beekeepers. Hence, the problem calls for a comprehensive cost-benefit analysis that integrates the stakes of diverse groups.

Furthermore, the erratic nature of desert locust population dynamics and their migratory activity suggest that risk should be treated in a formal and systematic way at the level of public decision-makers and at the farm level. The latter has been largely ignored in the past, because farmers' coping strategies of reactive control were considered simply ineffective. A discussion of basic risk containment strategies, namely diversification, flexibility, productivity and stability, however, reveals that farmers' means of adapting to their risky environment are more diverse and probably more effective than previously assumed.

To prepare the ground for a new concept of desert locust management evaluation, the basic concept of cost-benefit analysis is introduced. Finally, the required methodology for formal risk analysis is covered, including decision matrixes and the concept of expected utility maximization. These concepts are used to investigate the farm level decision situation and the significance of risk in the design of intervention strategies.

The third chapter assembles the framework for evaluating desert locust management. First, the objectives of intervention of governments and donors are discussed in view of evidence that aggregate food supply may depend more on other factors than on desert locust plagues. Subsequently, selected intervention approaches are examined. One attractive option is crop insurance because it can effectively protect the livelihood of affected farmers. Surveys in Ethiopia, Morocco and Sudan have revealed that poor farmers are willing to pay for insurance against crop losses due to desert locusts. Index-based insurance schemes provide a solution for reducing the administration cost. They offer non-farm businesses and individuals whose livelihood depends indirectly on agriculture, e.g. farm workers and rural small-scale processing businesses access to insurance. As a second strategy, relief disbursement to protect the livelihood and to maintain the productive capacity of the affected households is considered. However, the incompatible incentives put up by relief and the relatively high cost burden make it at least theoretically a less appealing option. As further alternatives, the continuation of the present control strategy and the improvement of control techniques with regard to cost savings and environmental side effects are considered.

The reference system for economic assessment of desert locust management interventions is developed stepwise and explained with the help of decision matrixes. First, the term economic loss is defined as the difference between expected net returns of two alternative strategies. According to this definition, desert locusts have to be taken as a natural constraint just as other factors influencing agricultural production. Economic loss is always bound to a sub-optimal decision on management strategies to cope with the natural adversities. The problem is further explored by accounting for the fact that decisions on locust management take place at two levels: the government level where large scale public interventions are decided and the farm level where the farmer adapts the farm plan to the perceived risk. It is shown that the choice of the decision tools influences the profitability of public intervention alternatives . A scenario of no government intervention but including farmer adaptation is proposed as a reference situation against which alternative public management strategies should be evaluated.

With the reference scenario being defined, the farm level analysis examines the role of desert locust risk and its perception by the farmer with regard to the choice of on- and off-farm risk containment strategies. This also includes a theoretical assessment of the factors determining the willingness to pay for crop insurance.

The following step in the economic evaluation includes aggregation and a revaluation of monetary values in efficiency prices to account for price distortions. Furthermore, the calculation of the market effects from supply shocks due to locust damage is highlighted in this context. As numerous parameters are subject to uncertainty, the framework is designed to use a Monte-Carlo-Simulation to obtain summary criteria like net present value or internal rate of return.

The methodology for including external costs is discussed in the next section. External costs of chemical control are likely to occur in the form of losses in production, human health costs and environmental costs. Suitable methods to obtain information on external costs are suggested.

The third chapter closes with considerations to include the (positive) international externalities that are attributed to plague and upsurge control. A game-theoretic model is introduced revealing that only side-payments that level the differences in costs and benefits from control between countries ensure a globally optimal provision of early control.

Chapter four elaborates on the methodology for data collection and analysis. As the concept primarily builds on farm data, farm budget analysis and partial budget analysis are important yet simple methods to assess the benefits of interventions to these groups. Two methods for the valuation of non-marketed goods are introduced, the group of dose-response approaches and the contingent valuation method. The latter has already been used to elicit the willingness to pay for insurance from farmers in different African countries. To obtain probability and risk-related information from the farm level visual elicitation methods for subjective probabilities and the Monte-Carlo-Simulation are described. The tool of stochastic dominance analysis is proposed to support decision-making based on the results of the analysis. It is capable of considering different risky strategies and a set of risk preferences in a systematic and transparent way.

Chapter five presents an example of the application of the framework. Wrapped in a discussion between the head of a desert locust control service in an African country and his staff, the new concept is brought to life using hypothetical figures and some controversy about methodological issues.

The main thread of the book closes in chapter six with an overview of the most important issues raised by the analysis. The presented framework goes beyond the scope of the traditional approaches in several ways. Firstly, it overcomes the restriction to a control/no control choice by allowing for consideration of alternative strategies apart from control. Secondly, building the analysis on actual farm data reduces the need for critical assumptions compared to a modeling approach. At the same time this allows for farmers' adaptation to be appropriately included in the analysis. Finally, uncertainty is accepted and treated consistently throughout the analysis so that decisions can be based on an improved information base. This should contribute to a transparent decision making process that is less susceptible to psychological pitfalls and political bargaining.

8 Glossary of terms

Actuarial premium

This term is used in connection with insurance. The actuarial premium represents the ↗expected value of the ↗indemnities paid back to the insured. It is calculated as the mean of the damage scenarios weighted with their respective probabilities. The actuarial premium or fair premium, is only part of the insurance premium, because the insurance company has to cover also administration and reinsurance costs.

Benefit

The term benefit generally refers to the contribution of any activity to social welfare such as increased income, improved environment or risk reduction. For economic analysis, the benefits are measured in monetary terms by quantification and valuation at their ↗opportunity cost or value in consumption.

Benefit cost ratio

The benefit cost ratio is sometimes used as a summary criterion in ↗cost-benefit analysis. It is the sum of discounted incremental benefits divided by the sum of the discounted incremental costs. Due to possible ambiguities in assigning effects to the benefit or cost categories, this performance indicator is not generally recommended.

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}}$$

Certainty equivalent

The certainty equivalent of a risky prospect is the sure payment that makes a ↗risk averse decision-maker equally well of as the risky payoff. Take for example a lottery where you can win $10 with a probability of 0.5 and nothing otherwise. The expected value of the lottery is winning $5. A risk neutral individual would be indifferent between the option to take part in the lottery or to get $5 for sure. A risk averse individual, however, would prefer the sure payment. But when the sure offer is stepwise reduced, say to $4, $3 or $2 at one point, the decision will turn in favor of the lottery. The sure payment at which the decision turns is the certainty equivalent of the lottery for that particular decision-maker. Certainty equivalents facilitate the comparison of different risky and sure prospects according to the preference of one individual. However, certainty equivalents for the same risky prospect depend on the individual's degree of risk aversion and have to be elicited separately for each decision maker.

Ceteris paribus

Ceteris paribus (often abbreviated c.p.) can be directly translated as "all other things being equal". It is a condition frequently cited in economic reasoning. As the interplay of many factors determines the reaction of an economic system, this provision is used to reduce complexity so that statements about the effect of changes in only one factor are possible. In economics, the c.p. condition provides controlled conditions in analogy to experiments in natural science.

Contingent valuation method

The contingent valuation method (CVM) is a method for valuation of goods for which no market and hence no price exists. It belongs to the direct methods of non-market valuation, because it directly infers from a consumer survey e.g. the ↗willingness to pay for a good or service. It is usually conducted in a survey in which the respondents are presented a hypothetical market scenario. The actual valuation question can come in different styles like open and closed-ended questions for the willingness to pay. In a referendum-style survey, respondents only have the choice to support or reject a proposed change in the provision of the good in question. The method has been applied to many valuation problems also in developing countries and is widely accepted in environmental economics. See also section 4.2.2 and appendix A-3.

Cost

Costs are a measure of the resources and goods used up in the process of producing benefits. In an economic analysis, the use of goods and resources is valued at their ↗opportunity cost, i.e. at the value of consumption or production forgone in alternative uses. Subtracting the costs from the benefits yields the net benefits or the net contribution of an activity to social welfare.

Cost-benefit analysis

Cost-benefit analysis (also social benefit cost analysis) is a methodology for the quantitative evaluation of public investment activities. It quantifies and values the ↗benefit and ↗cost components of a proposal in common units and allows the calculation of summary criteria such as ↗net present value and ↗benefit cost ratio. Through its quantitative rigor, cost-benefit analysis enforces transparency in the underlying assumptions of project planners. Hence, it is a major tool for communication and informed decision-making, although in many circumstances additional criteria are used along with the results of cost-benefit analysis.

Cumulative distribution function

The cumulative distribution function is one way of describing the probability distribution of a stochastic variable in full. By definition, it gives the probability of the random variable taking on values below the functions' argument: F(x) = P(X ≤ x). For continuous stochastic variables, it is a continuous and increasing function that can take on values between zero and unity. The graph of the cumulative density function follows an S-shaped curve for many standard distribution functions (triangular, normal). In risk analysis, the cumulative density functions of different variables can be compared with the means of ↗stochastic dominance analysis.

Discounting

Most individuals prefer getting $100 today to getting the same amount in a year's time. Due to this time preference, payments at different points in time are not immediately comparable. By discounting with the interest rate the present value of future payments can be obtained to make them comparable.

In the equation, B_0 is the present value of the future benefits B_t in period t with r being the interest rate.

$$B_0 = \frac{B_t}{(1+r)^t}$$

Discrete stochastic variable

A stochastic variable takes on random values. If there is only a finite number of values the variable takes on, we refer to a discrete variable in contrast to a continuous stochastic variable.

Economic loss

Economic loss only occurs, when a sub-optimal decision is made. The loss amounts to the difference in net benefits between the most profitable and the chosen strategy. As a consequence, from the viewpoint of decision analysis, desert locusts do not cause an economic loss, because they are beyond immediate human control. However, taking decisions on the management of desert locusts could involve economic losses. These could be caused by too high or too low investment in control activities or in the selection of a sub-optimal strategy or set of technologies to deal with the desert locust risk. This issue is discussed in detail in chapter 3.3.

Efficiency, allocative

Allocative efficiency or Pareto-efficiency refers to a state of economic affairs in which no reorganization of trade or production under given production technology and resource endowments could improve the level of satisfaction of one individual without lowering the satisfaction of another one. The rather theoretical notion of Pareto-optimality provides the yardstick for judging the efficiency of resource allocation.

For practical matters, among others, cost-benefit analysis provides a tool of operationalizing the Pareto criterion. Cost-benefit analysis reveals whether a proposal is Pareto improving, i. e. whether it increases the welfare of society.

Efficiency, technical

Put simply, technical efficiency means avoiding waste of inputs by producing a maximum with a given amount of inputs or to minimize input use for producing a given level of outputs. However, there is usually a wide range in which input and output levels satisfy this condition and only by including measures of scarcity of inputs and outputs will exactly specify a point of optimal input levels.

Elasticity of demand

The elasticity of demand is the percentage change in the quantity of a good or service demanded in response to a given percentage change in price or income, ceteris paribus.

There are three measures for the elasticity of demand. The *own-price elasticity* of demand (q) of a good measures the responsiveness of demand to a change in its price (p).

$$E_D = \frac{\Delta q}{\Delta p} \cdot \frac{p}{q}$$

For a pair of goods that are substitutes or complementary goods, the demand for one good (q_1) depends on the price of the other product (p_2). In such cases, the *cross-price elasticity* measures the relative change in demand of the one as a consequence of the relative price change of the other good.

$$E_{D1,2} = \frac{\Delta q_1}{\Delta p_2} \cdot \frac{p_2}{q_1}$$

The third measure is the *income elasticity*, which relates the change in demand (q) observed upon a change in income (Y). The sign and absolute values of the demand and supply elasticities determine who bears the largest

$$E_Y = \frac{\Delta q}{\Delta Y} \cdot \frac{Y}{q}$$

burden of a production shock, i.e. a sudden decline in supply.

Elasticity of supply

The price elasticity of supply is the percentage change in the quantity of a good or service supplied in response to a given percentage change in its price, ceteris paribus. It is hence a measure of the responsiveness of supply towards price changes.

$$E_S = \frac{\Delta q}{\Delta p} \cdot \frac{p}{q}$$

Expected utility maximization

Expected utility maximization captures the idea that many people facing risky decisions do not maximize the expected value of the payoffs but are ready to forego a certain amount for reducing the risk. This rational behavior can be described with the help of an ordinal utility function that ranks the individual payoffs according to the preferences of a decision-maker. If the utility function is known or some of its properties, the utility maximizing prospect can be calculated.

Expected value

The expected value of a risky prospect is the mean of the possible payoffs weighted with their respective probability. The expected value is commonly used to characterize the location of a probability distribution.

Externalities

External effects or externalities are the effects of one agent’s behavior on another agent’s well-being which are not reflected in market transactions. Positive external effects occur, when one agent provides a good and others can benefit from it without compensating the producer. Conversely, negative external effects arise when one agent incurs costs due to the economic activity of another without being compensated. External effects lead to a discrepancy between private and social costs, which in turn causes individual decisions to deviate from a social optimum.

Food insecurity

Food insecurity is a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life. It may be caused not only by the unavailability of food but also by insufficient purchasing power, inappropriate distribution, or inadequate use of food at the household level. Food insecurity may be chronic, seasonal or transitory (FAO definition).

Indemnity

On occurrence of the insured event, the insurance reimburses the insured with an amount of money called indemnity. The indemnity payment can cover the full or partial damage according to the conditions of the insurance contract.

Insurance premium

The purchase price of an insurance contract is called the insurance premium. The insurance premium is set by the issuing insurance to cover the ↗actuarial premium plus administration cost and an allowance for re-insurance if applicable.

Internal rate of return

The internal rate of return is an often-used performance indicator for investment projects. It is the discount rate that reduces the ↗net present value to zero. Hence, it represents the break-even rate of return of an investment. If the internal rate of return is higher than the investor’s opportunity cost of capital, the project is economically justifiable.

The internal rate of return has to be obtained from numerical approximation techniques, which do not always lead to a unique solution. Due to this difficulty and other critical assumptions, the internal rate of return is not recommended as the only criterion for project selection.

Marginal value, marginal cost

The marginal value is the value that is added by one more unit that is available for consumption. Marginal cost is the cost that is incurred by producing one more unit starting from a given level of production. The marginal cost corresponds to the first derivative of the cost function. As optimality conditions are often expressed with respect to marginal values, the concept of marginality plays an important role in economic reasoning.

NPV, net present value

The net present value is a common performance indicator for investments. It is defined as the sum of discounted benefits and costs of an investment. The net present value is the appropriate criterion for evaluating mutually exclusive projects.

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

Opportunity Cost

The desires of man are numerous (or insatiable) but the resources to satisfy these wants are limited. As a result, choices have to be made between the human desires that are ‘top priority’ (that must be fulfilled) and other desires that are of ‘lower priority’ (that may be left unfulfilled). The opportunity cost of fulfilling one desire is the cost (worth) of the alternative desire that has to be forgone. The central concept of opportunity cost is that goods and services are needed to produce other goods and services. For example, the opportunity cost of labor is the amount of money that could have been earned if say a farmer does not engage in farm production himself. Also, the opportunity cost of cultivating a parcel of land is the rent that could have been received if the land were to be rented out.

Preventive control

No universally accepted definition of preventive control exists and the strategy is still under development. But in principle, preventive control strategies aim at preventing the build-up of large and swarming populations and plagues by implementing monitoring and control activities in the potential breeding habitats of the desert locust.

Project

A project covers all activities in an undertaking that uses resources to gain benefits. The term does not only refer to aid projects but includes all interventions with specific goals and a clearly defined beginning and end. However, in desert locust management, projects could exceed the time horizon that is foreseen at the outset and would therefore rather be called programs. The methodology of evaluation of projects and programs is essentially the same. Hence, in this text there is no distinction between projects and programs and they are often referred to as “public intervention” in general.

Public good

A good is considered a pure public good if its consumption is non-rival and non-excludable. A good is non-rival in consumption when the consumption of one person does not reduce another person's consumption of the same unit of public good. Examples are the enjoyment of clean air or of a scenic view. Moreover, non-payers cannot be easily excluded from the benefits of pure public goods such as national defense or public health. As a consequence, no markets and no prices exist for such goods.

Risk

Risk characterizes a decision situation, where the outcomes of the decision depend on random variables whose state is not known at the time of decision making. Moreover, the term implies the preference for certain consequences.

Risk analysis

Risk analysis is the study of decisions under ↗risk. Its positive branch is concerned with the description and analysis of human behavior in view of risky decisions. The normative branch of risk analysis is concerned with the development of methods and decision rules for rational decision-making given risky prospects.

Risk attitude

The risk attitude is an individual's general approach to evaluating risky prospects. It is expressed in the functional form of the ↗utility function. Risk attitude can be grouped into three broad categories: Risk aversion reflecting a decreasing slope of the utility function, risk neutrality or indifference, which pertains to a constant slope of the utility function and risk preference reflected in increasing slope. Most people are risk averse when they face significant income or wealth risks, i.e. they are willing to forgo some expected return for a reduction in risk. The rate of the acceptable trade-off depends on the degree of risk aversion.

Risk aversion

Risk aversion is a category of ↗risk attitude that applies to decision-makers having utility functions with a decreasing slope. As a consequence, they are willing to forgo some expected return for a reduction in risk.

Risk premium

Risk averse decision makers are willing to forgo some expected return for a reduction in risk. The risk premium is the difference between the expected value of the risky prospect and its ↗certainty equivalent. With increasing degree of risk aversion, risk premiums for the same risky prospect increase.

Risk profile

The graph of the cumulative distribution function of a stochastic variable is also referred to as the risk profile of that variable because it contains the full information on the probability distribution. The risk profiles of alternative proposals can be evaluated with the help of ↗stochastic dominance criteria.

Stochastic dominance criteria

Stochastic dominance is a concept for comparing risky alternatives according to assumptions on the risk preference of a decision-maker. With each degree of stochastic dominance, more restrictive assumptions on the ↗risk preference of decision-makers are made to gain more discriminative power. The concept is applicable to continuous stochastic variables and is of a more general nature than the ↗certainty equivalent. See 4.4 for a detailed explanation of the stochastic dominance criteria in particular.

Stochastic efficiency methods

This term refers to methods that utilize information on complete distributions for deriving decision criteria that are consistent with expected utility maximization. Increasingly restrictive assumptions on the form of the decision-maker's utility function lead to increasingly discriminating criteria of stochastic dominance. Because the knowledge of the exact form of the utility function is not required, the conclusions of stochastic efficiency analysis hold for more than one individual decision-maker.

Subjective probability

The term subjective probability refers to an important concept of ↗risk analysis. Usually, probabilities are thought of as relative frequencies of a large number of cases observed in the past. These "objective" probabilities are often of limited usefulness, since either historical data simply are unavailable or some important conditions have changed that make them irrelevant for a description of future conditions.

Instead, decision analysis introduces the concept of subjective probabilities that express the individual's degree of belief in a certain proposition. The subjective probabilities are relevant for analysis because they apply to the decision-maker's belief about the uncertain setting of the decision, which is essential for a "good" decision according to the individual's preferences.

Uncertainty

The term uncertainty is used to characterize a situation of imperfect knowledge. Unlike the term ↗risk, uncertainty does not imply a preference for particular outcomes.

Value

The value of a good is the most an individual is willing to give up in exchange for the good out of the resources it currently controls (↗opportunity cost). As a consequence, in an economic sense no good has a value of its own or an inherent value. Value is always determined in relation to other goods and individual preferences. Although using monetary units as a common denominator is very convenient, value can also be expressed in kind.

WTA, willingness to accept

The term willingness to accept is used in connection with the ↗contingent valuation method for obtaining the value of non-marketed goods from hypothetical market surveys. It refers to the amount of money which would have to be given to the respondent to forgo a change and still be as well off as if the change proposed in the hypothetical market scenario had occurred. As this measure is beset with numerous problems in empirical surveys it is not generally recommended.

WTP, willingness to pay

The term willingness to pay is used in connection with the ↗contingent valuation method for obtaining the value of non-marketed goods from hypothetical market surveys. It is the maximum amount a respondent is willing to give in exchange of the good described in the hypothetical market scenario. The willingness to pay is a direct measure of the respondent's value in consumption.

9 References

Anderson, J.R., J.L. Dillon and J.B. Hardaker (1977): Agricultural decision analysis. Iowa State University Press, Ames.

Anderson, J.R. and J.L. Dillon (1992): Risk analysis in dryland farming systems. FAO, Rome.

Belhaj, M. (2000): The economics of desert locust - The case of Morocco. http://www.handels.gu.se/econ/EEU/rbelhaj.htm, 22-05-2000.

Binswanger, H.P. (1980): Attitudes toward risk: experimental measurement in rural India. *Amer. J. Agr. Econ.*, 65, pp. 395-407.

Chara, B. (1997): Control of the desert locust: strategy, organisation and means. In: S. Krall, R. Peveling and D. Ba Diallo (eds.): New strategies in locust control. Birkhäuser, Basel, Boston, pp. 475-485.

Cowan, R. and P. Gunby (1996): Sprayed to death: path dependence, lock-in and pest control strategies. *The Economic Journal*, 106, pp. 521-542.

Cole, D.C., F.Carpio and Ninfa Léon (1998): Conceptual and methodological aspects of investigating the health impacts of agricultural pesticide use in developing countries. In: Crissman, C.C., J.C. Antle and S.M. Capalbo (eds.): Economic, environmental and health tradeoffs in agriculture: pesticides and the sustainability of Andean potato production; Kluwer, Dordrecht, pp. 65-81.

Curry, S. and J. Weiss (1994): Project analysis in developing countries. The Macmillan Press, Houndmills, Basingstoke.

Dinwiddy, C. and F. Teal (1996): Principles of cost-benefit analysis for developing countries. Cambridge University Press, Cambridge.

Dixon, J.A. , D.E. James and P.B. Sherman (1989): Theeconomics of dryland management. Earthscan Publications Ltd., London.

Ehrlich, I. and G.S. Becker (1972): Market insurance, self-insurance and self-protection. *Journal of Political Economy*, 80, pp. 623-648.

Everts, J.W. (1990): Environmental effects of chemical locust and grasshopper control. A pilot study. FAO, Rome.

Everts, J.W. and L. Bá (1997): Side-effects of effects of chemical locust control: state of the art and perspectives. In: S. Krall, R. Peveling and D. Ba Diallo (eds.): New strategies in locust control. Birkhäuser, Boston, pp. 331-336.

FAO (1998): The state of food and agriculture 1998. Food and Agriculture Organization, Rome.

FAO (1999): Desert locust bulletin No. 243 (5 January 1999). FAO Emergency Centre for Locust Operations, FAO, Rome.

Fleischer, G., F. Jungbluth, H. Waibel and J.C. Zadoks (1999): A field practitioner's guide to economic evaluation of IPM. Pesticide Policy Project Publication Series No.9, Hannover, Germany.

Gardner, B.L. and R.A. Kramer (1986): Experience with crop insurance programs in the United States. In: P. B. R. Hazell, C. Pomareda and A. Valdés (eds.): Crop insurance for agricultural Development. John Hopkins University Press, Baltimore, Maryland, pp. 195-222.

Gittinger, J.P. (1982): Economic analysis of agricultural projects. Johns Hopkins University Press, Baltimore u.a.

Gudger, W.M. and L. Avalos (1986): Planning for the efficient operation of crop credit insurance schemes. Published for the International Food Policy Research Institute by the Johns Hopkins University Press, Baltimore.

Hanley, N. and C. L. Spash (1993): Cost-benefit analysis and the environment. Elgar, Aldershot.

Hanley, N., J.F. Shogren and B. White (1997): Environmental economics in theory and practice. Oxford University Press, Oxford.

Hardaker, J. Brian, Ruud B. M. Huirne and Jock R. Anderson (1997): Coping with risk in agriculture. CAB International, Wallingford.

Hassan, Z.E. (1998): Proposal of the University of Hannover for farm- and village-level case study in Yemen. unpublished, University of Hannover, Hannover, Germany.

Hazell, P. B. R., C. Pomareda and A. Valdés (1986): Crop insurance for agricultural development: issues and experience. Published for the International Food Policy Research Institute by the Johns Hopkins University Press, Baltimore.

Herok, C. and S. Krall (1995): Economics of desert locust control. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Rossdorf, Germany.

Houndekon, V. and H. De Groote (eds.) (1998): Health costs and externalities of pesticide use in locust and grasshopper control in the Sahel, Salt Lake City, Utah.

Huis, A. van (ed.) (1993): Can we combat the desert locust successfully? Wageningen Agricultural University, Wageningen, The Netherlands.

Joffe, S.R. (1995): Desert locust management : a time for change. World Bank, Washington, D.C.

Joffe, S.R. (1998): Economic and policy issues in desert locust management: a preliminary analysis. FAO, Rome.

Kay, R.D. (1986): Farm Management, planning, control and implementation. McGraw-Hill, Singapore.

Krall, S. (1994): Importance of locusts and grasshoppers for African agriculture and methods for determining crop losses. In: S. Krall and H. Wilps (eds.): New trends in locust control. TZ-Verl.-Ges., Rossdorf, pp. 7-22.

Krall, S. (1995): Desert locusts in Africa - A disaster? *Disasters*, 19(1), pp. 1-7.

Krall, S. (1997): New strategies in locust control. Birkhäuser, Basel [u.a.].

Kremer, A. (1992): Pests and donors in Mali, 1985-1990. *Disasters*, 16(3), pp. 207-216.

Lahr, J. (1998): An ecological assessment of the hazard of eight insecticides used in desert locust control, to invertebrates in temporary ponds in the Sahel. *Aquatic Ecology*, 32, pp. 153-162.

Little, I.M.D. and J.A Mirrlees (1974): Project appraisal and planning for developing countries. Heineman Educational Books, London.

Lomer, C.J., R.P. Bateman, D. Dent, H. de Groote, O.-K. Douro-Kpindou, C. Kooyman, J. Langewald, Z. Ouambama, R. Peveling and M. Thomas (1999): Development of strategies for the incorporation of biological pesticides into the integrated management of locusts and grasshoppers. *Agricultural and Forestry Entomology*, 1(2), pp. 71-88.

Magor, J.I. (1989): Joining the battle with the desert locust. *Shell Agriculture*, 3.

Magor, J.I. (ed.) (1993): Desert locust population dynamics. Wageningen Agricultural University, Wageningen, The Netherlands.

Mbodj, Y. and K.M. Lecoq (1997): Results and recommendations of the working group 'management strategies' - Working Group 1. In: S. Krall, R. Peveling and D. Ba Diallo (eds.): New strategies in locust control. Birkhäuser, Basel, Boston, pp. 509-513.

McCulloch, L. (unpublished): The Desert Locust Guidelines. Vol. VI: Campaign evaluation. FAO, Rome.

Mishan, E.J. (1994): Cost-benefit analysis: an informal introduction. Routledge, London.

Mitchell, R.C. and R.T. Carson (1989): Using surveys to value public goods: the contingent valuation method. Resources for the Future, Washington, D.C.

Nas, Tevfik F. (1996): Cost-benefit analysis: theory and application. Sage, Thousand Oaks, California.

Norton, G.W. and J.S. Davis (1981): Evaluating returns to agricultural research: a review. *Amer. J. Agr. Econ.*, 63, pp. 685-89.

Odihambo, T.R. (1988): The use and non-use of insects. The International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya.

Pannell, D.J. (1991): Pests and pesticides, risk and risk aversion. *Agr. Econ.*, 5, pp. 361-383.

Potter, C.S. and A.T. Showler (1991): The desert locust: agricultural and environmental impacts. In: W. Zartman (ed.) Tunisia: The political economy of reform. Lynne Rienner Publisher, Boulder and London, pp. 153-166.

Pesticide Policy Project: Training manual on economic analysis of crop protection policies. Pesticide Policy Project, University of Hannover, Hannover, Germany, draft to be published in 2001.

Rezende-Lopez, M. de and G.L. da Silva Dias (1986): The Brazillian experience with crop insurance programs. In: P. B. R. Hazell, C. Pomareda and A. Valdés (eds.): Crop insurance for agricultural development. John Hopkins University Press, Baltimore, Maryland, pp. 240-262.

Rola, A. and P. Pingali (1993): Pesticides, rice productivity, and farmers' health - an economic assessment. International Rice Research Institute (IRRI), Manila, Philippines.

Sadoulet, E. and A. De Janvry (1995): Quantitative development policy analysis. Johns Hopkins University Press, Baltimore.

Schroeder, A. (1999): SD's locust plague prevention - bridging the emergency response to development continuum. SD Developments, Office of Sustainable Developmnet, Bureau for Africa, USAID, Washington D.C.

Schulenburg, M. Graf v.d. (1992): Versicherungsökonomik - Ein Überblick über neuere Ansätze und Entwicklungen. *Wirtschaftswissenschaftliches Studium*, 8, pp. 399-406 (in German).

Showler, A.T. (1996): Desert locust control, public health and environmental sustainability in North Africa. In: W. D. a. A. B. Schwearingen (ed.) The North African environment at risk. Westview Press, pp. 217-239.

Showler, A.T. (1999): The desert locust in Africa and western Asia: complexities of war, politics, perilous terrain and development. http://ipmworld.umn.edu/chapters/showler.htm, 03-05-1999.

Siamwalla, A. and A. Valdés (1986): Should crop insurance be subsidized? In: P. B. R. Hazell, C. Pomareda and A. Valdés (eds.): Crop insurance for agricultural development. John Hopkins University Press, Baltimore, Maryland, pp. 117-125.

Skees, J., P. Hazell and M. Miranda (1999): New approaches to crop yield insurance in developing countries. EPTD Discussion Paper No. 55; International Food Policy Research Institute (IFPRI), Washington, D.C. http://www.ifpri.org/divs/eptd/dp/eptdp55.htm

Steedman, A. (1990): Locust handbook. Natural Resources Institute, Chatham.

Symmons, P. and K. Cressman (1992): The desert locust guidelines, vols. I-V. FAO, Rome.

Varian, H.R. (1999): Intermediate microeconomics: a modern approach. 5th edn., Norton, New York.

Waibel, H. (1990): Requirements for an Economic interpretation of crop losses. In: Crop loss assessment in rice. International Rice Research Institute (IRRI), Manila, pp. 313-320.

Waibel, H. and J.C. Zadoks (1996): Editorial foreword. In: Institutional constraints to IPM - papers presented at the XIIIth international plant Protection Congress (IPPC). The Hague. University of Hannover, Pesticide Policy Project Publication Series No.3, Hannover.

Walker, T.S. and N.S. Jodha (1986): How small farm-households adapt to risk. In: P. Hazell, C. Pomareda and A. Valdés (ed.) Crop insurance for agricultural development. John Hopkins University Press, Baltimore, Maryland, pp. 17-34.

Webb, P., J. von Braun, Y. Yohannes (1992): Famine in Ethiopia: policy implications of coping failure at national and household levels. International Food Policy Research Institute (IFPRI), Washington, D.C.

Whittington, D. (1991): Willingness to pay for improved sanitation in Kumasi, Ghana: a contingent valuation study. The World Bank, Washington, D.C.

Winpenny, J.T. (1991): Values for the environment: a guide to economic appraisal. HMSO, London.

Zadoks, J.C. and R.D. Schein (1979): Epidemiology and plant disease management. Oxford University Press, New York.

Appendix

A-1 Remarks on the theoretical foundations of cost-benefit analysis

Economic analysis of publicly funded projects is usually carried out in the framework of cost-benefit analysis (CBA). CBA draws on the principles of welfare economics. According to welfare theory, perfectly competitive markets[33] adjust allocation of resources to attain an optimum level through the price mechanism. A state of *Pareto optimality* is attained, when no agent can be better off without making another worse off. Only when market failures like imperfect competition, lack of information, the presence of externalities or high transaction costs impede markets from attaining a pareto optimum, government intervention can contribute to the welfare of society by providing public goods and services, regulating markets burdened with negative externalities, or by intervening with anti-trust legislation to keep the market mechanism working. Additionally, maintaining the income distribution along the socially desired norms is a task for government policies (CURRY and WEISS, 1994).

The Pareto criterion is very restrictive, since it limits welfare improvements to the rare case when no one is made worse off. The *potential Pareto condition* is regarded more practical, because it considers a policy as welfare improvment as long as those who gain are able to compensate the losers. Thus, the potential Pareto criterion, also referred to as the Kaldor-Hicks rule, justifies any reallocation that increases net social benefits (HANLEY and SPASH, 1993).

Iit is not required that the compensation payment is actually carried out. Thus the Kaldor-Hicks rule entails a selection of projects on economic efficiency grounds, precluding distributional issues from the analysis. It has been argued that the latter can be addressed by lump-sum transfers and that single biased redistributions are offset on average if a large number of governmental programs addresses different target groups (MITCHELL and CARSON, 1989).

---

[33] Perfectly competitive markets are characterized by the following criteria: (1) Perfect information about market transactions is available. (2) All firms are small in relation to the entire market, they are price takers. (3) A homogenous product is offered to many buyers at the market price. (4) There are no barriers or structural impediments to prevent firms from entering into or exiting from an industry. (5) Resources are completely mobile. (6) All factors of production are privately owned. (NAS, 1996)

CBA is a way of operationalizing a variant of the Pareto criterion by trying to place a dollar value on the gains and losses to those affected by a change in the level of provision of a public good. The value of a good is the most an agent is willing to give up in exchange for the good out of its initial resource endowments, or, the other way round, the least, the controlling agent is willing to accept in return for giving up the good. As a consequence, the value of a good depends on the current income distribution (MITCHELL and CARSON, 1989).

It must be noted, that CBA is founded on the acceptance of consumer sovereignty. This is the belief that the consumer is a better judge of what gives him utility than anyone else, thereby rejecting paternalism, the notion that the government, scientists or elite groups know what is best for the individual. Also egalitarianism or the belief that all individuals are entitled to a minimum standard of living are implicitly rejected, while the current income distribution is accepted as given (MITCHELL and CARSON, 1989).

In general, CBA emphasizes economic efficiency rather than distributional issues. However, the effect of a project or program on the income distribution can be studied within the CBA framework by separating gains and losses for different groups (MITCHELL and CARSON, 1989). The distributional information can be considered apart from the efficiency criteria for decision-making, or losses and gains may be weighted according to the groups affected (GITTINGER, 1982). CBA is a methodology to assess the social impacts of a project or program and originally its scope is a national economy. See section 2.2 for the steps in conducting a cost-benefit analysis. Details have been omitted here for brevity and can be taken from the relevant literature on project evaluation (CURRY and WEISS, 1994; GITTINGER, 1982; LITTLE and MIRRLEES, 1974; MISHAN, 1994).

A-2 External costs of desert locust control – available evidence

In chapter 3.6 the cost components of control were listed as an example for external costs of desert locust management interventions without details and literature references. This will be made up for in this appendix. Please see Figure 9 for an overview of the cost components that are discussed here.

Losses in production

Firstly, pesticides can have *phytotoxic effects* that reduce biomass production of pastures and fields. According to JOFFE (1998), only a phytotoxic effect of fenitrothion on sorghum is reported. Admittedly, adverse effects of pesticides on plant growth can be minimized by the thorough selection of agents and often by choosing control sites that are not used for agriculture or livestock. But recurrent reports on inappropriate application, storage, and handling, even to the extent that the shortage of other compounds can lead to the application of disapproved organochlorine insecticide stocks, qualify such optimism (JOFFE, 1995).

The valuation of decreased pasture and crop production due to phytotoxic effects will be considerably difficult, since damage depends on the agent applied and the type of crop. Case studies can be used to ascertain the physical yield decrease for different combinations of crops and agents. Then records of control measures on specific crops must be kept and evaluated. Pasture losses can be measured in terms of the final production goal, e.g. increase of livestock weight. Again such data are not yet available and must be obtained from case studies. The economic evaluation is straightforward when market prices can be used. Where market prices are distorted, shadow prices must be utilized, according to the above mentioned procedures.

Pesticide resistance is a phenomenon that is frequently reported of other pests (COWAN and GUNBY, 1996), while no account of pesticide resistance in desert locusts is known to the author. Nevertheless, this point should be kept in mind, because resistance increases control costs and can influence the long-term project costs.

Furthermore, there is evidence of effects of desert locust spray operations on the *productivity of livestock*. Besides anecdotal evidence of abortion in camels due to pesticide poisoning, there are reports of sheep dying after grazing on contaminated pastures (POTTER and SHOWLER, 1991) and unspecified livestock losses in Burkina Faso cited by HEROK and KRALL (1995). The fact that desert nomads regularly hamper survey and control operations in the areas they control, because they fear negative side-effects of pesticides on their livestock and bees (JOFFE, 1998), is an indication that these losses might be substantial.

Productivity losses due to mortality of honeybees after pesticide contamination are included at this point. POTTER and SHOWLER (1991) emphasize the importance of apiculture in Tunisia as a supplemental income source for small-scale farmers. Besides their honey production, bees have beneficial external effects as pollinators of many crops. The pesticides most frequently used in Tunisia are known to cause 75 to 100 percent mortality of bee colonies. Beekeepers were not warned before pesticides were applied in the 1988 campaign, and substantial losses were recorded (POTTER and SHOWLER, 1991).

There are two possible ways to assess the costs of these losses. Firstly, a production function approach that identifies the functional relationship between pesticide contamination and livestock productivity (weight increase and fecundity). The physical losses pastoralists incur can be valued with the market or shadow price for livestock. A thorough record keeping on treated areas and on the agents applied is the basis for calculating the physical loss in livestock production. The lack of continuous records on control efficacy and costs (JOFFE, 1995 and 1998) leaves not much optimism that the necessary bookkeeping will be accomplished, however.

A second approach would try to elicit the value of the production lost directly from the affected pastoralists and beekeepers, because they have a long established experience with public control interventions. This could be accomplished using the contingent valuation method (see section 4.2). Of course, the WTP survey must as well elicit socio-economic data and establish the factors that influence the willingness to pay in order to obtain a bid curve and to determine the validity of the CVM exercise. In this case, it is of particular interest whether the WTP amount increases with increasing size of the herd or the number of bee colonies.

The *loss of desert locusts as a source of food* is only rarely acknowledged. In many African and Asian countries, boiled or grilled locusts are not only consumed but even sold on markets (ODIHAMBO, 1988; SHOWLER, 1999). As they are a rich source of protein, they can also be used as livestock feed. Then a flour from dried and ground locusts is mixed with cereal flours (ANONYMOUS, 1998). Thus, chemical control entails also a decrease in the availability of this special diet. Where markets exist, a valuation of dietary desert locusts is not too difficult. The problem of measuring the quantities that would have been consumed without public control will remain a problem, though. This topic should be examined more closely if experience suggests that it is a substantial part of the costs. Closely related are health risks resulting from the consumption of contaminated desert locusts, which are considered in the human health cost category below.

A further source of productivity losses from chemical pesticides is *the reduction of beneficial organisms*. This topic covers that subset of the environmental effects that has a more or less immediate effect on crop production. JOFFE (1998) cites anecdotal reports of bird population reduction and emigration as a consequence of lacking arthropod food. EVERTS (1990) reports that at least 26 bird species and over 100 insect taxa are known to be natural antagonists of locusts and grasshoppers and that chemical control threatens them by secondary poisoning and food deprivation. VALK et al. (1999) found for grasshopper control, that pesticide application may substantially reduce parasites, parasitoid and predator populations. Experimental and anecdotal evidence of secondary pest upsurges after spraying against grasshoppers is cited by JOFFE (1998). This may be caused by the disruption of beneficial arthropod populations. In a few words, it is likely that chemical pest control reduces the self-regulation potential of the agro-ecosystem and hence increases production costs.

Again, it is difficult to assess these production costs – whether they come in the form of increased need for pesticide application by the farmer or by increased losses due to other pests. The difficulty is not the valuation of production losses, because market prices are available. Here again, the problem lies in the functional relationship between pesticide application and reduced populations of beneficial species and the effect of the latter on the production costs. In this field, in-depth studies are necessary to establish the complex relationships underlying the above named processes. Only then, an economic evaluation is possible.

Human health costs

Human health can be affected from pesticide application by direct dermal contact or ingestion of contaminated food. According to SHOWLER (1996), *direct exposure* to insecticides occurs mainly because of improper equipment maintenance, pesticide handling and application. In particular, the frequently observed omission of safety clothing is a problem (POTTER and SHOWLER, 1991). Although it is not common to measure pesticide exposure of application staff, in some countries cholinesterase titers in the blood of pesticide handlers and applicators were measured. It is known that during the 1986-89 campaign in Morocco, 1,000 persons were temporarily or permanently removed from spray operations upon low cholinesterase titers (SHOWLER, 1996). JOFFE (1998) gives US$ 795,600 as costs for medicines and medical personnel for the 1988/89 campaigns in Morocco.

Measuring these health effects is relatively easy once monitoring of contamination and sub-acute poisoning is compulsory. If personnel is moved out of pesticide operations when cholinesterase levels fall below toxicologically defined thresholds, health costs can be easily determined from the costs of the treatment and the loss of working hours. Using this method, a minimum estimate of costs is obtained, because individual suffering and chronic health effects are not yet considered. Also those health effects that are not measurable with cholinesterase titers will be missed by this approach.

Besides the control personnel, the *rural population* in general is at risk. While spray operations are often carried out in uninhabited areas or rangeland, nomads and bystanders still run the risk of direct contamination (POTTER and SHOWLER, 1991; SHOWLER, 1996). Even when the population is warned by radio broadcasts about imminent spray operations and advised against consumption of locusts, poisoning through direct contamination and ignorant ingestion of treated food crops and locusts are possible (ODIHAMBO, 1988). A further source of contamination is the contact with leaking pesticide barrels and the use of empty barrels as containers for food and drinking water (SHOWLER, 1996). These facts may not be blamed on the ignorant population but rather on poor storage conditions, too large stockpiles and the frequently observed carelessness of application personnel. As a consequence, the costs of these health effects must be included in the project account. Also the possible contamination of surface and ground water must be taken into account for human health impacts.

For an assessment of these external costs, information on the incidence of pesticide contamination and poisonings is necessary. In-depth monitoring of health effects on the population is only possible in the framework of a case study, since a close relationship to spray operations is lacking so far. As a consequence, an important part of the work will be to identify sources and intensity of contamination. This will be particularly troublesome for ground water contamination, because transport processes uncouple the source of contamination spatially and chronologically from the emergence of hazardous agents in drinking water. Another part of the case study will have to cover the effects of acute and sub-acute poisoning on human health and on the productive capacity to estimate at least the costs of foregone income.

POTTER and SHOWLER (1991) regret that information on the adverse effects of pesticides on human health is scarce in developing countries. But there are a number of case studies that measure health costs incurred by farmers who apply pesticides themselves. For example, in their case study on pesticide use in rice production in the Philippines, ROLA and PINGALI (1993) show that health costs are roughly double the pesticide costs. Notwithstanding the differences between ecosystems and application techniques, their estimate may be taken as a first approximation to the true human health costs, as long as no more specific information is available. An extensive overview of different approaches for measuring human health impacts is given by COLE et al*.* (1998).

Environmental costs

The last category of costs embraces all costs accruing from negative side impacts of pesticides that do not directly affect production or human health. Nevertheless, the pollution of soils, surface and ground water, the disturbance of ecosystems and the possible threat to the continued existence of species in fragile ecological balances are imminent results of extensive pesticide application. EVERTS (1990) reports findings from a pilot study that depending on the agent used, the entomofauna is severely affected short by after spraying. Some populations did not recover fully before the end of the rainy season. Besides harmful effects on aquatic invertebrates, the extermination of one fish species was observed after an application of a standard dosage of chlorpyrifos. POTTER and SHOWLER (1991) report that the Tunisian government has prohibited the application of desert locust pesticides in oases, because their fragile ecosystems are highly dependent on water and aquatic life which is known to be very sensitive to the utilized pesticides. They also fear that widespread pesticide application exacerbates the degradation observed in many other ecosystems as a consequence of unsustainable land use. The special concern for ecosystems that act as isolated refuges is also shared by EVERTS and BÁ (1997), while empirical evidence on adverse impacts of pesticides on their balance is still lacking. The damage potential of pesticide contamination of soil and ground water should also be considered in the framework of environmental costs.

While in the present list the effects were grouped with regard to the applicable valuation methods, a rather systematic overview of the environmental effects is given in EVERTS and BÂ (1997).

A-3 Supplement on the contingent valuation method (CVM)

The contingent valuation method has been presented in section 4.2.2. However, many of the drawbacks and theoretical difficulties were not discussed. Here the different issues that have been subject to criticism will be portrayed in short. A comprehensive overview is provided in MITCHELL and CARSON (1989) as well as in HANLEY and SPASH (1993).

The criticism of the CVM may be subsumed under the following headlines:

Strategic bias

The respondent in a CVM survey has an incentive to state a lower WTP than he actually has because public goods are non-excludable in consumption. She/he will benefit from an increase in the provision of the good even if she/he states a zero WTP as long as others are ready to pay for the improvement. On the contrary, a strategy to overstate the WTP in order to increase the probability of the improvement going ahead can bias the WTP survey upward.

Design bias

The design of the CVM survey may itself be a source of bias. The choice of the bid vehicle and the starting point in bidding games have been shown to influence the WTP. Also the information on the commodity in question provided along with setting up the hypothetical market influences the bid.

Mental account bias

In some surveys, a bias that originates in the decision-making process of the respondent has been noticed. It was observed that this process goes through two stages. In the first, the individual decides on the share of income (and wealth and time) to be spent on environmental goods in general. In a second step, this “budget” is allocated to the individual environmental assets of interest. It is assumed that in many cases the WTP for individual assets is overstated so that the sum exceeds the budget.

Hypothetical market error

Because the hypothetical market cannot mirror all important features of real markets, over or under statement of the true WTP may occur. For example, in hypothetical markets, no real payment is actually made. This might lead the respondent to neglect weighing thoroughly the trade-offs between more of the environmental commodity in question and less of something else (MITCHELL and CARSON, 1989).

Difference in WTP and WTA amounts

It has been largely demonstrated that estimates of WTA exceed the estimates of WTP obtained from CVM surveys considerably in many cases (HANLEY and SPASH, 1993; HANLEY et al., 1997; MITCHELL and CARSON, 1989). A number of reasons for this observation is put forward by different authors. HANLEY and SPASH (1993) provide the following explanation:

- Individuals value a given reduction in entitlements higher than an equivalent increase in entitlements (loss aversion).
- WTP bids are usually constrained by the income, whereas WTA bids are unconstrained.
- Risk aversion makes consumers, who will only be able to value the good once, overstate WTA and understate WTP, since they are uncertain on the true value they ascribe to the good.

Additionally, the high frequency of outliers and protest bids obtained in CVM studies using the WTA format and theoretical considerations suggest, that WTP is the preferable format. MITCHELL and CARSON (1989) review these issues in great detail. They also discuss a definition of property rights that allows the valid application of WTP estimates in many cases that were believed to necessitate a WTA form. Generally, they recommend the use of the WTP format wherever it is applicable. A number of further recommendations to overcome or circumvent some of the above mentioned issues has been compiled by HANLEY et al. (1997, p. 386) and MITCHELL and CARSON (1989).

Although most CVM studies have been applied to the valuation of environmental commodities in the developed world with a center of gravity in the USA, some applications in the developing world are reported (HANLEY and SPASH, 1993). WHITTINGTON (1991), in his case study on the use of CVM for determining the WTP for improved water services in Ghana, concludes that CVM surveys among poor and illiterate people may well be successful in obtaining reasonable and consistent answers. He stresses that the results show that the CVM is applicable to a wide range of public infrastructure projects in developing countries in general (WHITTINGTON, 1991). The CVM study of WAROLIN (1998) demonstrates an application to the desert locust problem in Ethiopia. Preliminary results of larger surveys in Morocco and Sudan are reported by BELHAJ (2000).

Despite these accounts of success, other authors warn of significant additional sources of bias, e.g. the lack of experience with market surveys among consumers that might put up hurdles of distrust. The opposite problem of politeness might urge respondents to give the “desired” answer (WINPENNY, 1991). Also the uneven distribution of incomes raises doubts where simplistic sampling and grossing up procedures are utilized. These issues must be considered where CVM is applied in the context of developing countries.

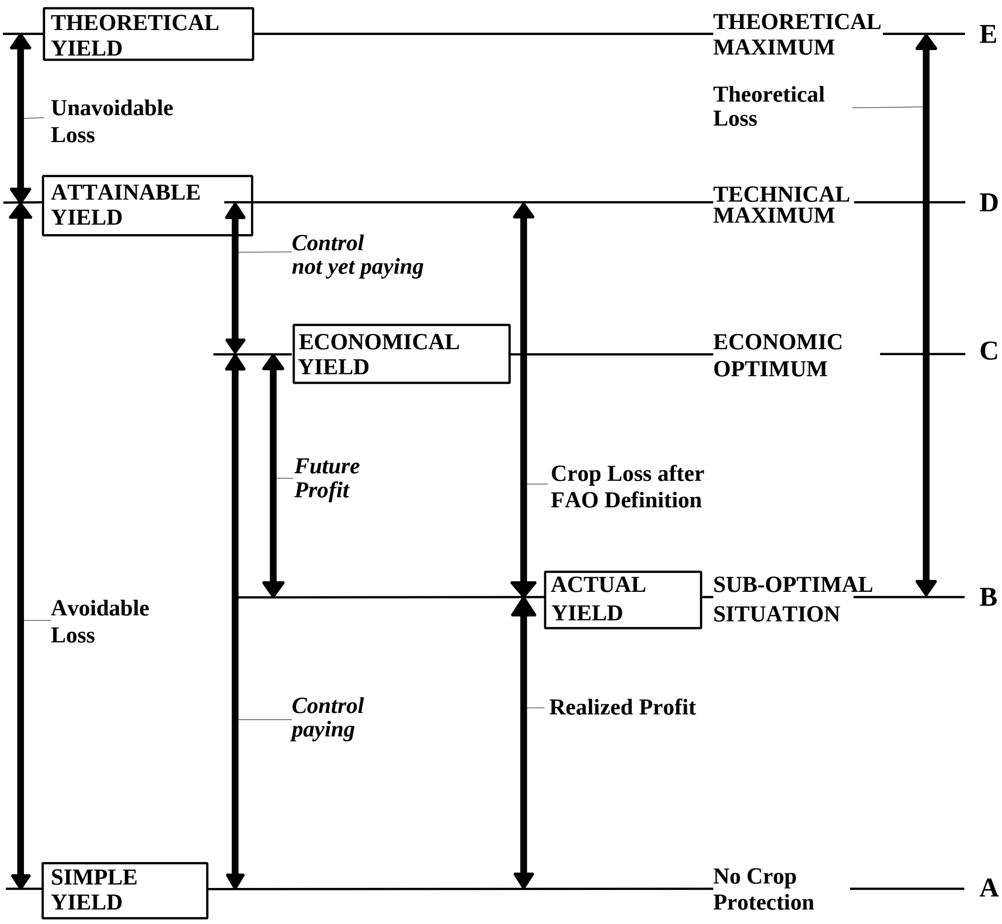
A-4 Definitions of yield loss

The reference system for the economic analysis of alternative public invention strategies was presented in 3.3 (p. 42). However, no reference was made to the underlying or resulting definition of yield loss. To close this gap, a short reference will be made to Figure 16, a frequently encountered diagram that represents different definitions of crop loss graphically.

Suppose the diagram refers only to yield losses caused by desert locusts. Then the variation due to other pests and climatic conditions (e.g. drought, hail) is not considered in the diagram, although they may be more important factors on a national level than desert locusts are.

The theoretical yield level (E) is of no interest here, because we are dealing with real farm yields. Assuming that the attainable yield (D) represents a yield level that can be attained by farmers under real world conditions, this corresponds to the yield without desert locust damage.

Figure 16: Yield levels and losses



Source: ZADOKS and SCHEIN (1979)

If locusts do invade, yield is reduced to a minimum level (A), if there is no intervention like spraying. However the label “No crop protection” is misleading because the severity or risk of pest incidence is influenced by many agronomic parameters. The decisions on parameters like planting date, varieties or soil preparation surely influence the probability and impact of a pest attack (although the latter two would be of little relevance in the case of desert locusts). As a consequence, determining the “simple yield” is usually an ambiguous matter.

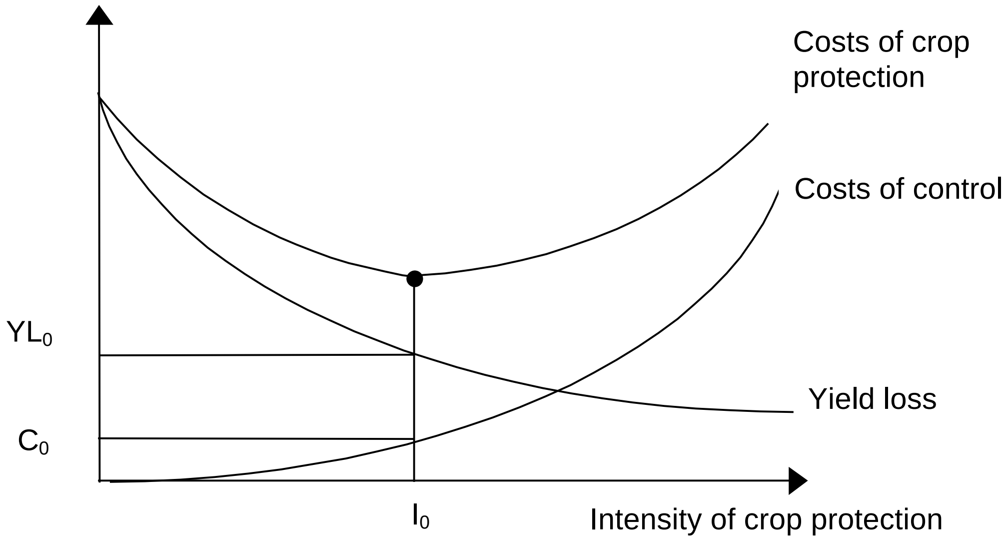
Yield level C recognizes that intervention is costly and only an economic proposition if at least a corresponding amount of the yield can be saved to balance the cost of intervention. As a consequence, there is a loss (D-C) that should be accepted without intervention, because an intervention would be more costly than incurring the loss. Within the range between C and B, crop protection efforts can reduce yield losses. The difference between B and A is labeled “realized profit” in the diagram. However, it should better be named “realized profits from additional crop protection”, because farmers could possibly make profits even from the so-called simple yield (A). In the graph, the actual yield level is labeled sub-optimal, because it is lower than the economic yield (C). Alternatively, a sub-optimal situation of too high investment in crop protection is imaginable. Then the actual yield (B) would be above economic yield (C) and economic losses would occur.

However, the considerations presented here, do not allow determining the optimal extent of crop protection efforts, because the price of the crop and the price of a unit of crop protection are not included in the analysis. This kind of consideration is accomplished by the definition of crop loss given under 3.3 with decision analytical tools and graphically in Figure 17.

For the economic definition of an optimal level of crop protection, consider Figure 17. The horizontal axis represents an increasing intensity of crop protection, while yield loss and control costs are shown on the vertical axis. The curve for yield loss represents the monetary value of lost produce and starts at a maximum if no crop protection is considered. With increasing intensity of crop protection the yield loss is reduced, although at a decreasing rate, until finally, additional crop protection activities cannot decrease the yield loss below a minimum value. On the other hand, the control costs increase from zero with increasing pace when crop protection is intensified. The increasing rate of control costs is due to a decreasing efficacy of each additional control activity when increasing levels of crop protection are applied.

The optimal intensity of crop protection is attained, when the cost of an additional unit of crop protection can just be recovered by the additional value of produce saved. This condition is met at (I_0), where the absolute values of the slopes of the cost and benefit curves coincide. This condition is equivalent to attaining the minimum of the cost curve representing the sum of the costs of control and the costs of yield loss.

Figure 17: Optimal level of crop loss and intensity of crop protection efforts



YL_0 = Optimal level of yield loss
C_0 = Optimal level of control costs
I_0 = Optimal intensity of crop protection

Source: FLEISCHER et al. (1999)

To make it quite clear, the optimal intensity of crop protection is not to be found at the point of minimal yield loss. It is rather attained at the minimum of the cost curve that represents the costs of yield losses and the costs of protection. As a consequence, the optimum depends crucially on the relative prices of crop protection and the produce, respectively.

For a more detailed discussion in a risk analytical framework see section 3.3 on p. 42.

A-5 Example of a CVM survey on desert locust crop insurance
(Source: HASSAN (1998))

QUESTIONNAIRE

(For socio-economic and WTP survey on economic evaluation of desert locust control at farm and village level in Yemen)

No. (___________) Date:___/___/ 200__

1- (a) Name? ________________________________ (b) Gender? ___ (c) Age? _____

(d) Resident in the village since when? _________________

2- Other members of the household? (a) Adults? _____ (b) Children (under 16)? ____

3- (a) Can you read? ___ (b) Can you write? ___ (c) Years of schooling? ___

4- Farm production last year?

	Crop	Quantity	Unit	Area	Unit
a.					
b.					
c.					
d.					
e.					
f.					

5- Animal rearing? and type?

6- non-farm jobs? income annually?

7- Is there anybody who helps you with remittances? Who? Last year in-kind and/or cash?

8- What is most dangerous to your harvest? Order (1 is most dangerous and so on).

Rats ( ); Drought ( );Birds ( ); Shortage of labor ( );

locust ( );Plant disease, specify ( ) _________________________;

Other animals eating plants, specify ( ) _________________________;

Other, specify ( ) _________________________.

9- Have you ever had damage to your harvest by locust? If yes, how many times in the last twenty years? When was the last time?

10- How much of your harvest did the locust eat in the last major invasion?

	Crop	Quantity	Unit	Area	Unit
a.					
b.					
c.					
d.					
e.					
f.					

11- Hazards to animals from locusts control?

12- Changes in crop patterns and/or agricultural operations due to locusts attacks? (also PRA)

13- Have you ever worked with locust campaigns organized from plant protection? Details?

14- (a) Do you know any local methods to control locust?

(b) Have you ever used such local methods to combat locust? Why? How? (PRA)

15- Could you know that locust will come before an invasion takes place? How? (PRA)

16- Have you ever had such a situation like in (15)? Which consequences had that concerning farming decisions or others (work migration)?

WTP Opening Statement

Crop production is very crucial for the well-being of farmers in Yemen. The risk of locust to agriculture is high. The government is undertaking big efforts to combat locust, nevertheless, there is no country or organization in the world that can guarantee 100% eradication of the swarms and so no damage what so ever to farmers' plots. On the other hand, everything now is expensive and so the control of desert locust. We want to know if you are ready to pay anything to diminish the risk to your subsistence (or production in case of market producers).

For this purpose, assume that there is a fund, in which every household in the village is going to participate with amounts of e.g. wheat once a year. This amount will be enough to completely compensate the losses to your harvest from locust damage.

17-

(a). Are you willing to participate with one sack of wheat every year and get full compensation for losses from locust?

Yes ___ Go to (b)

No ___ Go to (d)

I don't know ___ Go to (e)

(b). Would you be willing to contribute with 1½ sacks?

Yes ___ Go to (c)

No ___ Go to (e)

I don't know ___ Go to (e)

(c). Are you willing to contribute with 2 sack?

Yes ___ Go to (e)

No ___ Go to (e)

I don't know ___ Go to (e)

d). Are you willing to contribute with ½ sack?

Yes ___ Go to (e)

No ___ Go to (e)

I don't know ___ Go to (e)

(e). Think for a moment please. What is the largest amount of wheat your household is willing to participate with to get full compensation in the case of locust attacks?

Amount of wheat _______

I don't know _______

(Another starting point can be ½ sack).to remember that the difference between 1 and ½ sack may be very big for poor farmers.

18- Why did you answer like that in (17)?

(a). That is my maximum, I can't afford more.

(b). I think this amount is enough to compensate my losses.

(c). The government should protect us against such losses.

(d). I am not convinced that the idea of the fund is going to work.

(e). Desert locust is not a big danger for me.

(f). Other reason, specify? ________________________________

GTZ/University of Hannover PESTICIDE POLICY PUBLICATION SERIES:

AGNE, S., G. FLEISCHER, F. JUNGBLUTH and H. WAIBEL (1995): Guidelines for Pesticide Policy Studies - A Framework for Analyzing Economic and Political Factors of Pesticide Use in Developing Countries. Pesticide Policy Project, Publication Series No. 1, Hannover. (Also available in French and Arab).

MUDIMU, G.D., S. CHIGUME and M. CHIKANDA (1995): Pesticide Use and Policies in Zimbabwe - Current Perspectives and Emerging Issues for Research. Pesticide Policy Project, Publication Series No. 2, Hannover.

WAIBEL, H. & b J.C. ZADOKS (1995): Institutional Constraints to IPM. Papers presented at the XIIIth International Plant Protection Congress (IPPC), The Hague, July 2-7, 1995. Pesticide Policy Project, Publication Series No. 3, Hannover.

AGNE, S. (1996): Economic Analysis of Crop Protection Policy in Costa Rica. Pesticide Policy Project, Publication Series No. 4, Hannover.

JUNGBLUTH, F. (1996): Crop Protection Policy in Thailand - Economic and Poltical Factors Influencing Pesticide Use. Pesticide Policy Project, Publication Series No. 5, Hannover.

FLEISCHER, G., V. ANDOLI, M. COULIBALY, T. RANDOLPH (1998): Analyse socio-économique de la filière des pesticides en Côte d'Ivoire. Pesticide Policy Project, Publication Series No. 6/F, Hannover.

POAPONGSAKORN, N., L. MEENAKANIT, F. JUNGBLUTH and H. WAIBEL (eds., 1999): Approaches to Pesticide Policy Reform – Building Consensus for Future Action, A Policy Workshop in Hua Hin, Thailand, July 3 - 5, 1997. Pesticide Policy Project, Publication Series No. 7, Hannover.

WAIBEL, H., G. FLEISCHER, P.E. KENMORE, G. FEDER (eds., 1999): Evaluation of IPM Programs - Concepts and Methodologies. Papers presented at the First Workshop on Evaluation of IPM Programs, Hannover, March 16 - 18, 1998. Pesticide Policy Project, Publication Series No. 8, Hannover.

FLEISCHER, G., F. JUNGBLUTH, H. WAIBEL and J.C. ZADOKS (1999): A Field Practitioner’s Guide to Economic Evaluation of IPM. Pesticide Policy Project, Publication Series No. 9, Hannover.

MUDIMU, G.D., H. WAIBEL, G. FLEISCHER (eds., 1999): Pesticide Policies in Zimbabwe – Status and Implications for Change; Pesticide Policy Project, Publication Series Special Issue No.1, Hannover.

AGNE, S. (2000): The Impact of Pesticide Taxation on Pesticide Use and Income in Costa Rica’s Coffee Production, Pesticide Policy Project, Publication Series Special Issue No.2, Hannover.

AJAYI, O. (2000): Pesticide Use Practices, Productivity and Farmers’ Health: The Case of Cotton-Rice Systems in Côte d’Ivoire, West Africa; Publication Series Special Issue No. 3, Hannover.

JUNGBLUTH, F. (2000): Economic Analysis of Crop Protection in Citrus Production in Central Thailand, Publication Series Special Issue No. 4, Hannover.

Summaries of the publications and other project related information are also available at:

http://www.pesticide-policy-project.de