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Pesticide Policies in Zimbabwe

Status and Implications for Change

Godfrey D. Mudimu
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(eds.)

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Pesticide Policies in Zimbabwe – Status and Implications for Change

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List of Abbreviations

ACIA	Agro-chemical Industry Association
ADI	acceptable daily intake
AGRITEX	Department of Agricultural and Technical Extension Services
ARDA	Agricultural and Rural Development Authority
ATP	adenosine triphosphate
BRL	Blair Research Laboratory
CGIAR	Consultative Group of International Agricultural Research
CNS	central nervous system
CPU	catch per unit effort
CRI	Cotton Research Institute
CSRI	Chemistry and Soil Research Institute
DBCP	Dibromochloropropane
DCC	Drug Control Council
DDT	Dichlorodiphenyl trichloroethane
DR & SS	Department of Research and Specialist Services
EDB	ethylene dibromide
EPA	Environmental Protection Agency of the United States
ESAP	Economic Structural Adjustment Program
ETU	ethylene thiourea
FAO	Food and Agriculture Organization of the United Nations
GABA	antagonising y-aminobutyric acid
GAL	Government Analyst Laboratory
GATT	General Agreement on Trade and Tariffs
GCPF	Global Crop Protection Federation
GDP	Gross Domestic Product
GIT	gastrointestinal tract
GMB	Grain Marketing Board
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HSACO	Hazardous Substances and Articles Control Officer
HSB	Hazardous Substances Board
ILO	International Labour Organisation
IO	Industrial Organization
IPM	Integrated pest management
IPPC	International Plant Protection Convention
IPPM	Integrated Production and Pest Management

IT	Information Technology
KAP	knowledge, attitude, practice
MBTOC	Methyl Bromide Technical Option Committee
MCA	multi-criteria analysis
MOLA	Ministry of Lands and Agriculture
MRL	Maximum residue limit
NGOs	Non-Governmental Organizations
NRI	Natural Resources Institute
OPIDN	organophosphate-induced delayed neuropathy
OPS	organophosphorus pesticides
PBCU	Problem Bird Control Unit
PIC	Prior Informed Consent
PPRI	Plant Protection Research Institute
PTM	Potato Tuber Moth
R & D	research and development
SAP	structural adjustment program
SCP	Structure-Conduct-Performance
TRB	Tobacco Research Board
ULV	ultra low volume
TRT	Tsetse Research Team
UNEP	United Nations Environment Programme
UZ	University of Zimbabwe
WRT	Weed Research Team
WHO	World Health Organization
ZFC	Zimbabwe Fertilizer Company
ZW$	Zimbabwean dollars

Preface

The use of chemical pesticides in agriculture has increasingly become a matter of concern. While undoubtedly significant achievements in terms of production of agricultural commodities have been made in the last decades, the increasing trends of pesticide consumption in developing countries are seen as not compatible with the objectives of sustainable agricultural development. Negative effects on human health and the natural environment as well as on the natural resource base of agricultural production call for reconsideration of pest management strategies.

Integrated pest management (IPM) has been identified as the preferable strategy in view of meeting the requirements of sustaining high agricultural production levels in the long-term and preserving the natural resource base. Compared to reliance on unilateral chemical pesticide use in combating pests, diseases and weeds, IPM is built on the principle of combining all available and appropriate control measures in an integrated strategy with a strong preference on cultural control techniques, prophylactic measures of reducing pest pressure, and biological control methods. Pesticide use is seen as a last resort. Recognizing the proven feasibility of the IPM strategy, AGENDA 21 of the Rio de Janeiro conference on Environment and Sustainable Development demands the reduction of pesticide use and its negative consequences by placing more efforts on IPM introduction. However, economic, political and institutional factors in the crop protection sub-sector are often responsible for undervaluing the long-term benefits of shifting framework conditions towards increased adoption of sustainable land use practices in the agricultural sector of many countries.

Agricultural development in Zimbabwe is facing major challenges in contributing to sustainable development of the country. The sector accounts for 15 - 20% of the country's GDP. It generates about 60% of the foreign exchange earnings through exports of tobacco, cotton, beef and horticultural crops. Through backward and forward linkages with the non-agriculture sector, agriculture employs close to 40% of those in formal employment. Sixty to seventy percent of the country's 12.5 million people resident in the rural farming areas where they are directly dependent on agriculture for food security and most of their family cash income and employment.

Agriculture consumes almost US$ 60 million of chemical pesticides. Thus, Zimbabwe belongs to one of the major pesticide using countries in Sub-Saharan Africa. In view of the problems of increasing food demand due to a rising population and the degradation of the natural resource base in an environment of globalization and rapid technological change, strategic changes and institutional adaptations appear inevitable. Globalization of commodity supply for the international „supermarkets“ in major food importing regions of the world makes it necessary to meet the increasingly challenging quality standards. Concerns about pesticide residue levels among consumers have to be taken serious in order to defend and expand market shares. Likewise, obligations from international agreements restricting import and use of specific chemicals, such as the gradual phase-out of methyl bromide under the Montreal Protocol for Ozone-depleting Substances, alter pest management strategies in the country.

Also, on the national level, the contribution of a wide range of pest management options to food security, income of small-scale farmers, and consumer health and environmental protection has to be thoroughly considered. Concerns on the health consequences of indiscriminate pesticide use on farmers, farm workers and their families are among the top priorities in the discussion. In this context the role of the government, private non-profit and profit organizations which have been set under the area of the fast development of new chemical pesticides must be redefined.

It is a major challenge to the disciplines working in the field of pest management and agricultural development, i.e. plant protection specialists, biologists, toxicologists as well as economists and social scientists, to engage in a constructive dialogue on the future strategic options in crop protection. Taking its responsibility for initiating a dialogue among different disciplines and institutions, a workshop on PESTICIDE USE AND POLICIES IN ZIMBABWE was held by the University of Zimbabwe in the Department of Agricultural Economics and Extension, with the support of the Pesticide Policy Project of GTZ and the University of Hanover, from 20th to 23rd February, 1996 in Harare. It brought together experts with a background of different disciplines, i.e. crop protection specialists in research and regulation, natural scientists, and sector and policy economists.

The present volume represents the collection of the papers of the 1996 workshop that underwent review comments by international experts. The editors are grateful to the authors for elaborating and revising the papers, as well as to the reviewers. The approaches and methodologies used differ according to the subject and the viewpoints of the authors and should be seen as a starting point for interdisciplinary exchange and collaboration.

The chapters of the book highlight the current situation in the crop protection sub-sector from different angles. Natural, economic and institutional conditions for crop protection are analyzed as well as the regulatory and sector policies governing pesticide use. Two contributions are dealing with the negative effects of pesticides on human health and the environment. The book is concluded by two chapters that provide a perspective on requirements for improved benefit evaluation as well as on the objectives and first results of pesticide policy studies in several countries of the international Pesticide Policy Project which is conducted by the German Agency for Technical Cooperation (GTZ) and the University of Hannover.

The book starts with a review by CHIVINGE et al. of the plant protection problems in Zimbabwean agriculture which are largely explained by the increasing intensification of land use in the course of this century. A stronger focus on environmentally friendly pest management methods is demanded.

SITHOLE et al. give an overview of the major institutions involved in relevant plant protection research programs in Zimbabwe and their specific role. Although the role of pesticides in increasing agricultural production and maintenance of public and animal health standards is regarded as indisputable Zimbabwe is currently shifting towards an integrated approach to pest management (IPM) to ensure sustainable environmental safety.

KESWANI et al. highlight the present legislatory framework and regulations in the country. Present legislation only deals with manufacture, distribution, and sales, but is silent on pesticide use at farm level. A need to review Zimbabwe's pesticide registration requirements and regulations is identified, especially with regard to environmental impact assessment.

RUSIKE and MUDIMU are analyzing the structure in the pesticide industry that evolved out of the specific conditions of an import quota regime during the period of economic isolation of the country before independence. Perspectives for development during the ongoing process of economic liberalization are outlined.

KUJEKE is analyzing the information flow pattern that favor over- and misuse of chemical pesticides. There is need for a review of the policies and practices of pesticide management and use to ensure greater access to technical and general information for all stakeholders. With the on-going market reforms, the information requirements and obligations expected of the key public and private institutions need to be increased and clearly defined.

SUKUME analyzes the productivity of pesticide use in different sectors of agricultural production. Pesticide use patterns, namely in the commercial and the small-scale farming sectors, are dichotomous. The observed heavy use of pesticides in commercial relative to communal sectors is attributed to better access to credit and water, differences in agroecological regions, and lower yield risk. Estimates on price responsiveness of pesticide demand indicate a rather inelastic reaction.

NHACHI presents an overview on the relevance of toxicological research and monitoring of pesticide health impacts in Zimbabwe. The recommended safe use or handling of pesticides is tailored to the different pesticide toxicity as based on the color coding. However, over 50% of all farm workers in Zimbabwe are exposed to organophosphate pesticide compounds during the spraying season. Provision and use of protective clothing among farm workers in Zimbabwe is minimal and, together with poor knowledge of the health hazards of pesticides, contributes to the significant number of toxic exposures to pesticides in Zimbabwe.

Environmental impact assessment of pesticide use as a regular research and monitoring activity in Zimbabwe is still in its infancy. DDT has drawn much attention during the last decades since it is known as a persistent pesticide with a well documented ability to bioaccumulate through food chains and within food webs. As a result, it tends to have major population impacts at the higher trophic levels, particularly in birds. However, this compound is still subject to considerable debate. In Zimbabwe, DDT was used in tsetse fly control and is still in use in public health programs for malaria mosquito control. The paper of MAGADZA is a critical review of the controversy of the use of DDT in tsetse fly control.

Restricting the use of chemical pesticides by regulatory action is likely to pose adjustment costs on users since alternatives have to be applied. The paper of MAKAUDZE and SITHOLE is a specific case study on the economics of replacing methyl bromide. This chemical belongs to the ozone-depleting substances which are scheduled for a global phase-out. Effects on the financial viability at the private users' level are calculated using partial analysis techniques.

The paper of CHIKANDA deals with the impacts of the structural adjustment and economic reform program of the Zimbabwean government on the market and utilization of pesticides.

From a methodological point of view, the paper of WAIBEL is concerned with the frequent overestimation of the costs of adjustment to pesticide use restrictions. This is caused by the biased conception of the contribution of external inputs in long-term agricultural development and overall social welfare.

Finally, the results from Zimbabwe are put into the framework of global pesticide policy studies which are undertaken to build a solid information basis for national and international policy makers for initiating pesticide policy reform. FLEISCHER presents the general framework of analyzing economic, institutional and political factors that lead to overuse of chemical pesticides and presents results from case studies in Costa Rica, Thailand and Côte d'Ivoire.

The book is a reference point for discussion on policy approaches and as an important step for future action in changing pesticide policies. The introduction of a participatory training approach on integrated production and pest management (IPPM) in small-scale cotton production provides promising perspectives for a substantial change in pesticide use practices with secondary impacts on national institutions. It can be expected that the adoption of a farmer-centered extension and training approach will bring Zimbabwe into a leading position in the region.

The current status of pesticide use and policies in Zimbabwe presents some issues which deserve generic research in the country. This holds especially true for detailed case studies on the productivity of different pest management options, both, in the large and the small scale farming sector. Impacts of health damage on small farmers and farm workers in large scale farms need an economic assessment in order to be better taken into account into decision-making at national policy level. In view of the increasing dependency on consumer preferences at the global level, residues in exported agricultural produce are an important issue. However, residues in food and the environment deserve more attention also at the local and national level. Interdisciplinary collaboration including economic assessment should be enhanced.

The Editors — Harare and Hannover, September 1999

1 Trends in Agricultural Pest Problems and Management Strategies in Zimbabwe

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Abstract

Pests (insect pests, diseases, viruses, nematodes, vertebrate pests and weeds) have threatened crop production worldwide, Zimbabwe included, since man started agricultural activities. Before the arrival of the white settlers in 1890 in Zimbabwe the local population was successfully growing crops such as tobacco, millets, maize, tomatoes among others without use of pesticides but there were no pest outbreaks. The land use system involved intercropping and long fallows both of which reduced pest incidence and improved soil fertility. With the arrival of the settlers the pattern of agriculture changed from 1907 as large tracts of land were put under monocropping. This type of land use system created an environment conducive for pest outbreaks due to the ecological imbalance and reduction in biodiversity hence favored specific pests. Consequently several pest outbreaks were recorded for the first time in Zimbabwe and among them were the armyworm in 1909, rodents in 1912, several disease in the 1920s, aquatic weeds in 1937 and queleas in early 1940s. Since then current trends in pest infestation is that more and more frequent outbreaks have been occurring over shorter intervals and for some of the pests, such as the armyworm, locust and rodents outbreaks, are almost on a yearly basis.

Ever since the outbreaks started their management mostly involved use of pesticides though environmental friendly methods were also available. The justification of using pesticides is that they quickly control the pest. However, the main problems with pesticide usage is poisoning of nontarget species such as what occurred in livestock as early as 1913 when several cattle died due to arsenal poisoning and more recently the widely publicized and recognized environment pollution. There has been several recorded cases in Zimbabwe of human poisoning and water bodies pollution where aquatic life is adversely affected. Due to these problems there are several issues which need to be

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looked into. These include use of environmentally friendly pest control methods such as biological control, where it is feasible, and integrated pest management (IPM). Several cases of successful biological pest control exist in Zimbabwe. There is need to determine the balance between using the large amounts of pesticides and the social cost/benefits. Social costs are not easy to quantify and effects of pesticide usage are far reaching. There is also need for more research in the biology of pests so as to have a better understanding of their behavior and increase chances of using more environmentally friendly methods. The government should also adopt IPM as a national strategy for pest management in order to reduce pesticide usage.

1.1 Introduction

Insect pests, diseases and weeds have threatened crop production since man began agricultural activities. Methods used to combat the various pests differ across different agricultural systems. However, use of pesticides plays a major role. The concept of total pest destruction or eradication has been found to be unrealistic, hence the adoption of carefully planned pest control and management approaches took place.

Pests can be divided into weeds, phytopathogenic fungi, bacteria, viruses, vertebrate pests, insects (arthropods), arachnids and nematodes. In many agricultural systems, insect pest and disease outbreaks are no longer disasters which must be accepted but are now a manageable and manipulable phenomenon (RABBINGE, WARD and VAN LAAR, 1989).

Zimbabwe has experienced outbreaks of pests mostly since about 1900. Armyworm outbreak first occurred in 1901, quelea in the early 1920s, rodents around 1940 and diseases and weeds since about 1970 (WEINMAN, 1972). Most of the documented details on outbreaks are from the 1950s onwards. Outbreaks are a result of the introduction of commercial agriculture.

1.2 Development of agriculture in Zimbabwe

Zimbabwe is an agricultural country where over 70% of the population is directly dependent on agriculture (crops, livestock and forestry resources). Zimbabwe's traditional agriculture dates back 3000 years (BEACH, 1977) and it formed the backbone of a vibrant economy. Before the settlers arrived in 1890, the locals were growing a wide variety of crops such as finger millet [*Eleusine coracana* (L.) Gaertn.], bulrush millet [*Pennisetum typhoides* (Burm. f.) Stapf & Hubbard], sorghum [*Sorghum bicolor* (L.) Moench], maize [*Zea mays* (L.)], pumpkins (*Cucurbita* species), tomatoes (*Lycopersicon esculentum* Mill.), sweet potatoes [*Ipomoea batatas* (L.) Lam.], cowpeas [*Vigna unguiculata* (L.) Walp.], yam (*Dioscorea alata* L.), cassava [*Manihot esculenta* Crantz.], pineapple [*Annnas comosus* (L.) Merrill], lemons [*Citrus limon* (L.) Burm.f.], pawpaw (*Carica papaya* L.), mangoes (*Mangifera indica* L.), among others, with millet being the staple food (PALMER, 1977, quoted by RUKUNI and EICHER, 1994). These crops were grown successfully, until about 1920, without synthetic pesticides but using predators, parasites, cultural practices and natural pesticides.

The land use system was fairly similar in the whole country. Intercropping increased biodiversity and crop rotations of up to 15 years, to maintain soil fertility and reduce insect pests, diseases and weeds, were usual practices thus explaining the sustainable crop production which was in place. Crops and animals were selected for better performance through observations. Records were rarely kept if at all but knowledge was passed from one generation to another by word of mouth or folklore (RUKUNI, 1994).

By 1904 there were 545 white farmers in Zimbabwe and from 1907 the pattern of agriculture started changing. Large tracts of lands were opened and planted to monocrops. Imported seed of maize, tobacco (*Nicotiana tabacum* L.), wheat (*Triticum aestivum* L.), sorghum, groundnut (*Arachis hypogaea* L.) and sunflower (*Helianhus annus* L.) cultivars were introduced (ARRIGHI, 1967). In 1930, large scale commercial farmers owned 19.9 million hectares, communal farmers 8.7 million hectares and small scale commercial farmers 3.0 million hectares (RUKUNI, 1994). A lot of crop research including use of fertilizers and pesticides was taking place at this stage. Ecological imbalances resulted in reduced animal and plant biodiversity and created conditions favoring specific pests. By the mid-1920s, population pressure was building up in the communal areas due to land shortage. Consequently, fallow periods were reduced and pest incidences increased. Pest outbreaks such as those of the armyworm which occurred six times between 1914 and 1930 and that of the locust in 1924 started to occur with increasing frequency and in some cases annually (WEINMAN, 1975). High pest build-up started occurring hence from about 1945 large quantities of pesticides were used in such crops as tobacco, cotton and maize. In the 1960s most large scale farmers in Mashonaland area virtually practiced monoculture (WEINMAN, 1975), a situation which favored pest build-up.

After 1980, contributions of the smallholder farming sector in maize and cotton production increased substantially and by 1985 accounted for more than 50% of the cotton (MARIGA, 1994). There was also an upsurge in pesticide usage in many crops. Pests outbreaks have now increased in all the farming sectors and pesticide usage has dramatically risen up especially with the boom in horticultural production in recent years. The increased use of pesticides, whose effects on the environment and non-target animal and plant species was not monitored, has resulted in serious environmental pollution. Consequently many animal and plant species which were natural enemies of several pests have since been drastically reduced or completely eliminated, resulting in serious social and economic consequences.

1.3 Causes and management of pest outbreak

Case histories of some of the frequent pest outbreaks include locust, quelea, foot and mouth diseases in cattle, newcastle diseases in chicken, armyworm (*Spodoptera* species) water hyacinth [*Echhornia crassipes* (Mart) Solms] and Kariba weed (*Salvinia molesta* D.C. Mitchell). Some of these are discussed below.

1.3.1 Locust

Localised periodic locust outbreaks have been a normal occurrence in Zimbabwe since the 1920's. LAWLEY recorded a severe outbreak in the drought year of 1898 (WEINMAN, 1972). The more harmful red locust (*Nomadacris septemfasciata* Serv.) also made its first appearance around this time after being absent for many years unlike the less harmful brown locust (*Locustana pardalina*) which had always been in Zimbabwe (WEINMAN, 1972). To combat the outbreak, biological control using a fungal toxin was successfully implemented in the 1897 and 1898/99 seasons (WEINMAN, 1972).

Except for few isolated outbreaks reported in 1903, the country was rid of the red locust during the subsequent years (WEINMAN, 1972). However, further outbreaks occurred in 1906 and 1907. After that outbreak a mixture of sodium arsenite and sugar was used for controlling the pest. This was the first chemical control on locust in Zimbabwe. Twenty-one tons of arsenite were imported in 1907 for killing 14 000 swarms. Between 1910 and 1922 the country was completely freed from locust outbreak (WEINMAN, 1972). However, a severe outbreak of *L. pardalina* which occurred in 1924 was controlled using arsenical (WEINMAN, 1972).

More serious outbreaks of both the migratory locust (*Locusts migratoria migratorioides* R&F) and the red locust (synonym *Nomadacris septemfasciata*) occurred in 1932/33. Further major outbreaks of the red locust occurred in the 1933/34 season, causing considerable damage especially to the maize crop. The locusts were eradicated using parasites and diseases, particularly the locust fungus (*Empusa grylli*). Invasion by the red locust which caused a lot of damage in 1935 occurred along the eastern border of the country followed by smaller ones in 1936-39. However, the country was free of locust invasion by 1945 and no outbreaks were recorded for the next 27 years. Details of the area affected, damage levels and the control methods used over the period 1890 to 1972 are scanty (WEINMAN, 1975). The next cycle of outbreaks then occurred in 1972, 1977/78, 1986, 1987/88, 1989, 1993/94 and 1994/95.

Since the first recorded outbreak, chemical control has been the main method despite the fact that other methods such as bio-control and physical barriers were also effective. Currently, the only method being implemented is chemical control while pheromones are being successfully used for predicting and early warning of possible outbreaks. Development of other management practices has not been fully exploited.

Since locust outbreaks occur almost annually, there is an urgent need to find environmentally friendly methods of controlling them in order to reduce pesticide usage and consequently environmental damage.

1.3.2 Rodents

The first rodent outbreak occurred in 1912 and further ones were in 1920, 1932 and 1956 (WEINMAN, 1972; 1975). The rodents caused extensive damage to cotton bolls (about 30%) in 1956 (WEINMAN, 1975). The next outbreak took place in 1967/68 while subsequent ones occurred in 1975/76, 1983 and 1993/94. However, data on damage levels is scanty and was based on rough estimates. There is therefore a need to accurately quantify crop losses incurred due to current outbreaks. However, crop damage in the field average 5 to 30% though higher levels occur depending on the crop, rodent species, season, locality and intensity of outbreak. For example, in 1994, 5415 ha of maize were affected in the south eastern part of the country (Lowveld) and damage was about 80%, which is extremely high as it will result in losses of over 10 tons of maize. The number of rodent species in Zimbabwe is about 29 and those of economic importance are giant rat (*Cricetomys gambianus*), house mouse (*Mus musculus*), black rat (*Rattus rattus rattus*) multimammate (*Mastomys natalensis*) and the velvet rat (*Aethomys chyrophilus*).

Rodent outbreaks in Zimbabwe, like any other pest, are due to the current land use systems which reduce biodiversity and create an environment conducive for an upsurge in pest numbers. In general, outbreaks occur after a period of drought during which time natural control such as diseases, competition and predators such as snakes, owls, falcons, hawks, cats and jackals, are killed or reduced in numbers. Shortage of alternative food at this time could also affect the number of natural enemies.

The general trend regarding rodent management involves use of pesticides which is financially and environmentally expensive. Some of the rodenticides in use include warfarin, scillirocide, broadifacoum, coumatetryl and flocoumafen.

Management practices in use which are environmentally friendly though not as quick acting as rodenticides are trapping, digging the burrows and flooding of burrows with water. There is therefore need for accurate prediction of outbreaks, so as to use prophylactic action, which would reduce use of rodenticides.

Rodent outbreaks are now an annual occurrence but the biology and ecology of the pest and causes of outbreaks are not well understood. This information is essential for implementing other control strategies which do not use chemicals. Therefore there is an urgent need for concerted effort to generate detailed data on the biology and ecology of this group of pests.

1.3.3 Armyworm

JACK (1930) gave a detailed account of the armyworm (*Spodoptera exempta* Wlk.) outbreak between 1909 and 1930. The first recorded armyworm outbreak occurred in Mutare during the 1909-10 season though it did not cause damage as it occurred late in the cropping season. Five other outbreaks between 1915 and 1930 (see Annex 1-1). Two points emerge regarding the outbreaks. Firstly they were occurring in the large scale commercial farming sector, which is an indication of the reduction in biodiversity. Secondly, subsequent ones became more frequent and causing greater crop damage. The most destructive armyworm caterpillars are those hatched first while those emerging later are largely destroyed by natural enemies such as the *Chalcid* spp.

The main crop species affected belong to the Poaceae family and maize is the main target. In addition, white potatoes (*Solanum tuberosum* L.), peanuts, field beans (*Phaseolus vulgaris* L.) and sunflowers are also severely attacked. Caterpillars also prefer fields with grasses such as *Eleusine indica* (L.) Gaertn and *Eragrostis apera* Jacq. Nees. and *Rottboellia cochincinensis* Lour W. D. Dayton. The crop is therefore a target when the field has fewer or no grass weeds. In such situations, herbicides which completely remove weeds worsen the outbreak.

The armyworm is consistently attacked by various natural enemies (insects, diseases and birds). Examples include the white stock (*Cinonia alba*), the white billed stock (*Abdimia abdimii*), bristly flies of the family Tachinidae and stringless wasps in the family Chalcididae. The main disadvantage of biological control is its slow action and failure to completely eradicate the pest. Vigilance on the part of the farmer would allow detection of the pest one week or more before any damage. There will be no need to use pesticides or there will be a reduction in the frequency of their application. Chemical control has the advantage of being fast and removing the pest before much damage occurs. However, it has problems of environmental pollution and killing of non-target organisms, an issue discussed later in this paper. As armyworm invasion depends to a large extent on crop management, there is then a need to accurately determine crop management practices which reduces invasion by this pest and hence drastically reduce the need for pesticide application.

1.3.4 The quelea

The red billed quelea [*Quelea quelea lathamii* (Smith)] has been a greater menace than the locust since about 1940s (MUNDAY and JARVIS, 1989). The outbreak of the quelea has been as a result of planting vast pieces of lands to wheat, barley (*Hordeum distichum* L.) and Oats (*Avena sativa* L.). The clearing of large forests has reduced both plant and animal biodiversity thus making the crops an easy target for quelea invasion. Quelea prefer small grains of grasses such as jungle rice [*Echinocloa colonum* (L.) Link], *Eurochloa panicoides* Beauv. and *Paspalum orbiculare* Forst. They also eat insect larvae if available. Each quelea weighs between 15 and 23 g and their average daily consumption constitute 10% of their own weight but this varies with season. Quelea eat more just before and during breeding. Annual estimated crop damage is about 10-15%. The feeding area can cover 388 km^2. Zimbabwe was estimated to produce 80 000 tons of wheat during the 1995 winter season of which 12,000 tons (a reduction of 15%) was expected to be destroyed by quelea. The soft milk stage of the wheat is more vulnerable to quelea damage compared to the hard grain stage. Often, damage is caused by juveniles of the quelea which emerge out of local breeding colonies nearest to the cultivated lands (JONES, 1972). Some grain falls to the ground but the degree of wastage depends on the crop and stage of growth. Control of the quelea at the appropriate crop growth stage reduces damage. Damage due to quelea is also related to agronomic factors of time of planting and ripening of the wheat in relation to quelea migration (ELLIOT, 1979). Hence timely operations of some of the agronomic practices related to wheat production, on their own, will reduce crop damage and also result in a reduction in pesticide usage**.**

Since the problem started, management has been based on chemical control. Other management practices that minimizes pesticide usage have not been extensively explored. The conventional view of the farmers on quelea is that they must be eliminated by use of pesticides. This is one of the major reasons for the unjustified use of large amounts of chemicals. While quelea control has occurred in the past 30 years, the extent of losses to crops due to quelea damage or the impact that control has had on increased crop yields has not been accurately quantified. The reason being that most of the information has been based on surveys which are mostly inaccurate and overestimate the level of damage. The quelea numbers has since become increased due to more and more land being cleared and so are supplies of winter cereals. Based on this information farmers are prompted to use larger quantities of pesticides and more frequent sprays. What is needed is accurate empirical data on crop damage levels and levels of quelea control, for wise decisions to be taken on use of the correct quantities of the various pesticides. This will go a long way to reduce pesticide usage.

Despite the fact that the cost of damage to the crop has not been accurately assessed on an annual basis, thousands of liters of pesticides have been applied to kill quelea. For example, in an attempt to protect 80,000 tons of wheat crop expected in the 1995 winter season, about 5,000 liters of fenthion was applied. Over 800 million quelea have been killed in Zimbabwe alone in the past 23 years but there seem to be no justification for such action. However, the quelea numbers have not been reduced but appear to be increasing and crop damage levels remain the same or are even higher in some seasons. This is possibly so because the large amount of chemicals being applied are reducing the natural enemies, which also kill the bird. In order to control the quelea in Zimbabwe, explosives were first used in 1955 but were found to give unsatisfactory results due to a low kill, a high degree of maiming and destruction of non-target organisms. A combination of petrol and diesolene, which achieved a 95% kill, was then introduced. However, this was abandoned in 1959, in favor of chemical control because of diesoline total destruction of the roost habitat and severe hazard to fire (MUNDAY and JARVIS, 1989).

From 1959, quelea were controlled using parathion, a broad spectrum organophosphate which affects several domesticated and wild life forms hence is dangerous to aquatic organisms and grazing cattle (VAN ROOYEN and LOURENS, 1958) and other animals. In 1966, use of parathion, was abandoned in favor of fenitrothion which was less toxic and applied by air. Fenitrothion, which was in use until 1972, is more target specific and was as lethal to small birds as parathion, but far less toxic to other animals and human beings (POPE and WARD, 1972). Currently, ground-based mistblower mounted on tractors which achieve a kill of 95% are being used. Aerial spraying is now only done in circumstances which prevent use of mistblower. However, use of pesticides still causes environmental pollution and death of many non-target organisms leading to a reduction of natural enemies and the associated social problems such as chronic illnesses due to pesticide poisoning.

There is a need for farmers, extension agents and researchers to consider several issues in order to reduce pesticide damage to the environment, non-target species, reduction of natural enemies, which assist in reducing pest numbers, and impact on human health. Reduction in pesticide usage can only come about through an agreement between all the interested parties and major players (farmers, researchers and extension agents) on the magnitude of crop damage and extent of the problem. Researchers should gather accurate and authentic data. This will result in a better understanding of the problem, biology of the pest, improvement in pest management and finding ways of minimising pesticide use. Sprayers such as aircraft and mistblowers should be properly calibrated to ensure efficient deposition of pesticides on the target and minimise effect on non-target organisms and the environment. Since about 50% of the quelea population die annually due to several causes, including control (JONES, 1980), there is therefore a need to determine these causes and enhance their action as they are an environmentally friendly management strategy.

One of the solutions to reduce pesticide usage and crop damage due to quelea would be to grow winter cereals with bigger grains or those with sharp awns to deter the birds from eating the grain. It has been observed that improvements in agronomic practices and other crop management practices sometimes have far greater impact on increased crop yields than prevention of bird damage. For example, late harvesting due to insufficient machinery can result in losses from shattering which might exceed damage from quelea. There is therefore a need to find ways of improving agronomic practices which enhance reduction in crop damage due to quelea, resulting in reduced pesticide usage. This will then improve the quality of the environment.

1.3.5 Other pests

Besides the pests described above there are other insect pests (Annex 1-2) which also attack various crops and reduce yields by 15 to 100%. The damage varies from crop to crop depending on the intensity of infestation. Some of these pests are crop specific while others are common among many crops. In terms of their control, the current trend is leaning towards use of pesticides.

1.3.6 Plant diseases

Disease outbreaks are restricted to particular crops and are season dependent. Losses due to plant pathogens depend on several factors such as type of pathogen, crop species and growth stage when the pathogen occurs, duration of infestation and planting patterns. Complete losses may occur particularly for seedling diseases, but losses of 10 to 50% are common. Though most disease outbreaks occurred after the 1940s a lot more such as rust in cereals and leaf blight due to *Macrosporium* diseases or *Alternaria* spp. in tobacco, potatoes and tomatoes were there as early as 1904 (WEINMAN, 1972, 1975). Others which occurred later were leaf spot (*Cercospora nicotine*) angular spot (*Pseudomonas angulata*) and wild-fire (*Pseudomonas tabaci*). Since then more and more diseases on different crops have occurred (Annex 1-3). The most recent being the grey leaf spot (due to *Cercospora zeae-maydis*) in maize and frog eye in soybeans. The grey leaf spot has devastated the maize crops and will reduced yield by 500,000 tons during the 1996/7 rainy seasons and farmers have already spent ZW$ 86 million on fungicides. Due to a large number of diseases which occur in horticultural crops the largest use of fungicides has occurred in this sector.

As most diseases easily kill a crop within a very short period, the first reaction of the farmer, when the crop is affected, is to apply fungicides which are quick acting. Much of the seed sold for planting is dressed with fungicides to prevent seed-borne diseases. However, cultural practices including general sanitation, use of disease-free material and resistant cultivars are also commonly used. The unfortunate situation, when it comes to control, is the increase in the use of fungicides which is common across all the farming sectors.

In the case of plant diseases, one of the most reliable, easily to be implemented, and environmentally friendly methods of control is cultural practices. Removal of crop residues and crop rotation will go a long way in preventing diseases outbreak in many horticultural and field crops.

1.3.7 Weeds

Weeds are a major group of pests which drastically reduce crop yields depending on weed species and density, crop species, degree of infestation, soil fertility and environmental factors. Generally, most weed infestations are not as dramatic as insect attack or diseases infection though weeds generally reduce crop yields more than all the other pest combined together. Most weeds occur annually and seasonally but there is a lot of variation in intensity. They are common among arable and plantation crops though exceptions occur. Some of the major weeds are shown in Annex 1-4.

Aquatic weeds such as water hyacinth [*Echhornia crassipes* (Mart) Solms] which was first reported in Zimbabwe in 1937, water lettuce (*Pistia stratoites* L.) and Kariba weed (*Salvinia molesta* D.S. Mitchell) may resurge annually in large numbers warranting immediate large scale control, using herbicides.

Weed management in the large scale commercial farming sector mostly utilizes herbicides, supplemented with hand hoeing and tractor-drawn implements. Over 95% of the lands under arable and plantation crops in large scale commercial farms are treated with herbicides while farmers in the smallholder sector mostly use hand hoeing and ox-drawn implements. For aquatic weed management, herbicides have had limited success, in some cases, while biological control has proved to be very effective and long lasting. For example, the Kariba weed which first invaded Lake Kariba in 1959 and had covered 1000 km^2 (21.5%) of the water surface (5544 km^2) in 1962 (Annex 1-5), was successfully controlled using a grasshopper (*Paulinia acuminata*) MITCHELL and ROSE (1979). The weed is no longer a problem in the lake. However, application of paraquat and sodium arsenite was unsuccessful (THOMAS and ROOM, 1986).

More than 142,000 liters of 2,4-D and large amounts of glyphosate have been intensively used in Zimbabwe to control water hyacinth since 1953. However, the problem is increasing each year. Due to the interaction of 2,4-D and other chemicals being introduced into Lake Chivero, there has been a lot of pollution hence fish and other aquatic fauna have been dying. Between 1978 and 1991 over US$ 1.7 million was spent on chemical weed control of water hyacinth but up to now there has been no lasting solution in terms of its control. However, biological control using two weevils (*Neochetina eichhorniae* Warner) and *Neochetina bruchii* Hustache (CHIKWENHERE, 1994) effectively controls the weed, while CHIKWENHERE and FORNO (1991) successfully controlled *Pistia stratiotes* L. with *Neohydronoma affinis* Hustache.

For effective weed management, one of the most important tools is detailed information on the biology and ecology of the species in question. Information on seed germination or vegetative sprouting behavior, growth form and propagule development, dispersal and seed dormancy will make it easy to control weeds without resorting to use of herbicides. This will reduce environmental pollution and the associated negative effects of pesticides on human health and life in general and the associated negative effects.

1.3.8 Crop pest problems

The diversity of climate, soil and altitude makes Zimbabwe most suitable for the production of a variety of crops including cereals, oil seed crops, legumes, cotton and horticultural crops. At the same time these conditions are conducive to thriving populations of such pests as insects, pathogens, nematodes, weeds and vertebrate pests like rodents and quelea birds. These pests are capable of causing considerable crop losses.

Cereals

Economically, stemborers are the most important insect pests of cereals in Zimbabwe (BLAIR, 1969, 1977). Important species are maize stem borer (*Busseola fusca*) and sorghum stem borer (*Chilo partellus)*. Maize, sorghum and millets are affected and infestations range from 30 to 70% (SITHOLE, 1988, 1990).

Leafhoppers (*Cirdulina spp*.) transmit the maize streak virus, cutworms (*Agrotis spp.*), white grubs (*Eulepida mashona)* and *aphids (Aphis maidis* and *Aphis sorghi*) are other pests attacking cereals and pesticides are used in their control.

Maize streak virus, leafblights, seed rots, rusts and smuts are cereal diseases of economic importance. The maize streak virus infections can reach up to 100%, depending on the season and loses upto 30% in crop yield can occur (MZIRA, 1984). Grain rots are more prevalent in the humid season and cause yield losses of up to 20%, depending on the level of infection (SITHOLE and CHIKWENHERE, 1994). Root lesion nematodes such as *Pratylenchus spp*. are often associated with maize yield losses greater than 50% (MUCHENA, 1988).

Oilseed crops

Cotton, soybean, sunflower and groundnuts constitute the oilseed group of crops. The group is attacked by pests such as bollworms, termites, leafhoppers, aphids, mites and rodents.

Diseases like leafspot, virus diseases and wilts cause up to 80% infection but yield losses have not yet been quantified. In soybean, *Pyrenocheata glycinis* can cause yield losses of 10-55% (ROTHWELL, 1983). Rosette virus is the most import viral disease in groundnuts and causes plants to be stunted and fail to form pods and causes yield losses as high as 20%. The bollworms (*Helicoverpa armigera* and *Diparopsis castanea*) cause about 60% yield reduction on cotton; while wilts and blackarm disease cause substantial loss (GLEDHILL, 1976; BRETTELL, 1986).

Tobacco

Disease problems of tobacco include leafspots, soreshin, damping-off and wilts. Damping-off may reduce crop yields units by 30% (GARMIN, 1986). Cutworms, whitegrubs, false wireworm and nematodes are pests of economic importance in tobacco nursery beds.

Legumes

Legumes constitute an important source of protein in the small scale farming sector; especially as a substitute of meat. Beans and cowpeas are subject to attack by a wide range of insects including beanfly, bean striped weevil and red spider mites.

The most serious disease of pulses is the Bean Common Mosaic virus (BCMV) which attains incidences up to 100% and is responsible for losses up to 80%. Angular leaf spot and bacterial blight are other disease of economic significance.

Horticultural crops

The horticultural industry is expanding on a yearly basis for both home and export markets. However, there has been a concomitant increase in pest importance related to the industry. Important pests of vegetables, particularly brassicas include leafminers, red spider mites, fruit flies, tuber moths, cutworms and blackrot. Aphids are important pests of a wide range of horticultural crops including potatoes, tomatoes and brassicas. Leafminers, red spider mites, thrips, aphids, root-knot nematodes and powdery mildews attack cutflowers produced under glasshouse conditions. Soil pests including cutworms, white grubs, scarabaeid larvae, false wireworm and nematodes are economically important in nursery beds of many horticultural crops (SITHOLE and CHIKWENHERE, 1994). Deciduous trees like apples, apricots, pears and plums are mostly affected by root rot and dieback. Citrus quality is reduced by a virus causing the greening disease.

Coffee berry disease of coffee leads to a crop yield loss of up to 80% in the absence of fungicidal control measure. Fusarium bark disease causes losses ranging from 15 to 85% while yield losses due to coffee rust reaches up to 30%. Insect pests damaging coffee include leafminers, mealybugs, fruitflies, antesia bugs, caterpillars and scale insects (SITHOLE and CHIKWENHERE,1994).

1.4 Chemical usage in Zimbabwe

Pesticide usage in the agricultural sector in Zimbabwe started in the early 1900s. Since then there has been an increase in the number of pesticide groups on the market, for controlling various pests, frequency of use and type of spraying equipment. For fumigation purposes, fumigation chambers were installed in Harare, Bulawayo and Mutare as early as 1904 (WEINMAN, 1972). Since 1918, government has been supplying pesticides free of charge for locust, armyworm and quelea control. This has encouraged farmers to use chemical control at the expense of all other methods. There has not been much effort put in finding alternative ways of control, which are environmentally friendly and possibly even less costly. As commercial agriculture enlarged and new crop varieties were introduced, pest problems also increased. This then necessitated more frequent sprays resulting in environmental pollution and death of both non-target animals and plant species resulting in a reduction in biodiversity. This has some social costs to the society which are difficult to quantify. Use of pesticides has drastically reduced the natural enemies which are also effective in controlling all groups of pests. Some of the large operations, such as quelea control and spraying of large fields, involve use of aircraft but as reported by AKESSON and YATES (1984), PIMENTEL and LEVITAN (1996) and MAZARIEGOS (1985) only 25% to 50% of the pesticide reach the target when aerial spraying is done. Studies have suggested that pesticide usage in the USA could be reduced by 35 to 50% without a decline in crop yields (OTA, 1979; NAS, 1989). This practice should also be possible in Zimbabwe if studies on alternative methods of control are found. PIMENTEL et al. (1993) reported that use of pesticides does not always produce corresponding reductions in crop losses. Even with a ten-fold increase in the use of insecticides in the USA from 1945 to 1989, total crop losses from insect damage nearly doubled from 7 to 13%.

Another problem with excessive use of pesticides is development of pest resistance to the chemical. For example, continuous use of dimethoate on the red spider mite (*Tetranychus* spp.) in Zimbabwe, a major pest of cotton and other crops, has resulted in the pest developing resistance to this compound and other chemically related acaricides.

The efficiency of spraying pesticides is very low resulting in unnecessary amounts being applied or more frequent sprays. These include knapsacks, handheld ultra low volume (ULVs), boom sprayers, tractor-mount boom and aircraft sprayers. Between 1913 and 1923 there were many cases of animal poisoning in Zimbabwe due to arsenal, and 47 out of the 108 cases in 1921 were due to dipping (BLACKSHAW, 1921). Chemical spraying of quelea has also killed 52 bird species (TALBORT, 1977) (Annex 1-6). KASILO et al. (1991) reported 606 cases of organophosphate poisoning, between 1980 and 1990, in six central hospitals in Zimbabwe, resulting in a mortality rate of 8%. Other poisoning cases in Zimbabwe were reported by BWITITI et al. (1987), NHACHI (1988, 1989). MHLANGA and MADZIYA (1990) indicated the presence of large amounts of pesticide residues in Lake McLlwaine (Lake Manyame) which supplies water to the capital city, Harare, Chitungwiza and Norton with a population of about 2 million people. Evidence of agricultural pesticide residue built-up in lakes were reported by GREICHUS et al. (1978) and WESSEL et al. (1980). This information is a very small fraction of the indication of the environmental damage, which occurs in Zimbabwe, due to pesticides. There are many more animal, plant and other species which are negatively affected but are unaccounted for.

The direct and indirect benefits and risks of pesticide usage in Zimbabwean is complex and needs to be thoroughly studied and quantified. There is even a greater need to determine the balance between the use of such large amounts of pesticides and social costs or benefits so as to come up with better usage of pesticides.

1.5 General discussion

Chemical control has a lot to offer in terms of pest management, they also cause a lot of associated environmental pollution and health problems because everybody, everywhere, at some stage, is exposed to some pesticide residues in food, water and the atmosphere. There is therefore a need for a holistic approach to the whole issue of pesticide usage. The technical aspects and social issues of pesticide usage need to be addressed.

The integrated pest management (IPM) approach or other environmentally friendly methods, such as biological control, should be used where it is appropriate. There are many examples of successful biological control in Zimbabwe. THOMAS and ROOM (1986) reported that use of *P. acuminata*, which is an environmentally friendly management technique, controlled Kariba weed in Lake Kariba, was more effective and economic compared to application of paraquat or sodium arsenite. The white fly (*Bemisia tabaci*) is being successfully controlled by a parasitic wasp of the *Eretmocerus* spp in some horticultural crops (WILSON, 1996). *Trichoderma harzianum*, a fungus, is widely used in Zimbabwe for controlling soilborne pathogens (MAFUTA, 1994). The use of polyhedrosis virus for controlling semi-loopers in soyabeans is being successfully implemented (KUNJEKU, 1986) and is comparatively cheaper.

Vigilance is essential for detecting a pest before it becomes widespread and necessitates applying large amounts of pesticides. The practice should be widely used for monitoring the armyworm and locust, as it is effective in Zimbabwe. Government should encourage research into and use of environmentally friendly pest management practices. Examples include supporting research in integrated pest management, biotechnoloy and the need to emphasize research on the biology and ecology of the major pest. This would go a long way in reducing the amount of pesticides being applied for different pests. Use of crop rotation, which greatly generally reduce pest, should be considered seriously. SHALK and RATCLIFFE (1977) reported that combining crop rotation with the planting of corn varieties resistant to the corn borer and chinch bug, would avoid total insecticide used in corn whilst concurrently reducing insect losses. In the case of weeds they should only be removed when really necessary and not necessarily total elimination. SCHWEIZER (1989) reported that by avoiding total elimination of weeds, herbicides use can often be reduced by up to 75%.

There are several issues which need to be rectified if Zimbabwe is to reduce pesticide usage.

1. There are problems with pesticide application machinery which relate to calibration, worn-out nozzles and inappropriate and faulty nozzles. These result in excessive amounts of pesticides being introduced into the environment. Pesticide applicators should ensure that calibration is done properly and regularly and that correct nozzles are fitted to the sprayers, in order to reduce pesticide drift, which can be up to 30% of the applied chemical. Use of inappropriate spraying equipment has also led to excessive exposure to pesticides, especially to those applying the chemicals.

2. The majority of people applying, mixing, storing or dealing with pesticides in one way or another do not wear or use the appropriate protective clothing. This is the case besides effort and advice given by the agro-chemical companies and the Agricultural Chemical Industry Association (ACIA), among other practitioners. There is a need for concerted effort to train people in safe handling of pesticides as some of them are completely ignorant of poisoning due to pesticides.

3. Failure to correctly identify the pest, especially diseases and insect pests, has led to the wrong pesticides being applied, For example there are many

cases in Zimbabwe where fungicides are used to control insect pests and vice versa. Since the pest will not be controlled, the response of the farmer will be to apply more of the pesticide, further polluting the environment.

4. Lack of awareness by many people, especially on the chronic effects, of pesticides on human health has led to most people dealing with pesticides, adopting a casual attitude towards use of protective clothing. Some of the negative effects on human health may persist even after the termination of an acute poisoning incident as reported by (ECOBICHON et al., 1990.). Hence pesticide abuse which is rampant in the country is partly due to ignorance. There is need for more effort to make people aware of the dangers of pesticides by training at grassroot level.

5. Failure to observe the safe period between time of spraying and harvesting, especially in the case of leafy vegetable, is a major problem. Many people, unknowingly, eat vegetables bought at the markets containing pesticide residues.

The issues of health raised in the discussion and the few examples of pesticide poisoning which have been given underscore the serious nature of environmental and socioeconomic costs of pesticides. They also emphasize the great need for more detailed investigations of the environmental and economic impacts of pesticides in Zimbabwe. As pesticides are and will continue to be a valuable tool for pest control, there is a need for more accurate and realistic cost/benefit analysis so as to minimize the risks and develop and increase the use of non-chemical pest control. It is therefore everyone's duty to ensure that pesticide usage in Zimbabwe is minimized for the benefit of the society.

References

Akesson, N.B. and W.E. Yates (1984): Physical parameters affecting aircraft spray application pp. 95-115. In: W.Y. Garner and J. Harvey (eds.): Chemical and biological control in forestry, American Chemical Society Series 238, Washington, D.C. pp. 95-115.

Arrighi, G. (1967): The political economy of Rhodesia. The Hague: Mouton.

Beach (1977) The Shona economy: branches of production. In: R. Palmer and N. Parson (eds.): Roots of rural, poverty in Central and Southern Africa. London: Heinmann.

Blackshaw, G.N. (1921): Arsenical poisoning of cattle. Rhodesia Agricultural Journal, Vol. 18, pp. 188-190.

Blair, B.W., (1969): A preliminary report of the sex pheromones of the maize stalkborer *Busseola fusca* (Lepidoptera: Noctuidae). Rhodesia Agricultural Journal, Vol. 17, pp. 55-59.

Blair, B.W. (1977): Recent research on maize stalkborer *Busseola fusca* Fuller (Lepidoptera: Noctuidae). Rhodesia Agricultural Journal Vol.68, pp. 11-12.

Brettell, J.H. (1986): Some aspects of cotton pest management in Zimbabwe. Zimbabwe Agricultural Journal, Vol. 83, pp. 41-46.

Bwititi, T.B., O. Chikuni, R. Loewenson, W. Murambiwa, C.F.B. Nhachi and N.Z. Nyazema (1987): Health hazards in organophosphate use among workers in the large-scale farming sector. Central African Journal of Medicine, Vol 33, pp. 120-126.

Chikwenhere, G.P. and I.W. Forno (1991): Introduction of *Neohydronomus affinis* for biological control of *Pistia stratiotes* in Zimbabwe. Journal of Aquatic Plant Management, Vol. 29, pp. 53-55.

Chikwenhere, G.P. (1994): Biological control of water hyacinth (*Eichhornia crassipes*) in Zimbabwe - results of a pilot study. FAO Plant Protection Bulletion, Vol. 42, No. 4, pp. 185-190.

Ecobichon, D.J., J.E. Davies, J. Doull, M. Ehrich, R. Joy, D. McMillan, R. MacPhail, L.W. Reiter, W. Slikker and H. Tilson (1990): *Neurotoxic effects of pesticides*. In: C.F. Wilkinson and S.R. Baker (eds.): The effect of pesticides on human health. Princeton, NJ: Princeton Scientific Publication Company. pp. 131-199.

Elliot, C.C.H. (1979): The Quelea as a major problem in food deficient continent. In: A.P. Munday and M.J.F. Jarvis (eds.): Africa's feathered locusts. Harare: Boabab Books.

Garmin, R. (1986): Tobacco news, The Farmer, Vol.56, No. 16, pp. 23-24.

Gledhill, J.A. (1979): The Cotton Research Institute, Gatooma. Rhodesia Agricultural Journal, Vol. 76, pp. 103-118.

Greichus, Y.A., A. Greichus, H.A. Draayer and B. Marshall (1978): Insecticides, polychlorinated biphenyls and metals in African lake ecosystems. II Lake McLawaine, Rhodesia. Bulletin of Environmental Contamination and Toxicology, Vol. 19, No. 4, pp. 444-453.

Jack, R.W. (1930): The Armyworm (*Laphygma exempta* WLK). The Rhodesia Agricultural Journal, Vol. 27, pp. 912-924.

Jones, P.J. (1972): The status of *Quelea quelea* in Botswana and recommendations for its control. Report to the Government of Botswana, Botswana.

Jones, P.J. (1980): The annual mortality of *quelea* in South Africa from ringing recoveries during a period of intensive *quelea* control. Proceedings of the Pan-African Orrilhal Congress, Vol. 4, pp. 423-427.

Kasilo, O.M.J, T. Honane and C.F.B. Nhachi (1991): Organophosphate poisoning in urban Zimbabwe. Journal of Toxicology, Vol. 11, pp. 269-273.

Kunjeku, E. (1986): Potential use of insect viruses for control of soyabean pests. In: D.L. Cole (eds.): Soyabeans in Southern Africa. Proceedings of the workshop for the Southern African region on the basics of soyabean cultivation and utilization. Harare, Zimbabwe, 24 February- 7 March, 1986.

Mafuta, C. (1994): Biological control and plant-growth enhancing properties of *Trichoderma*. MSc thesis, Crop Science Department, University of Zimbabwe.

Mariga, I.K. (1994): Cotton research and development. In: M. Rukuni and K.E. Eicher (eds.): Zimbabwes' Agricultural Revolution, pp. 219-233.

Mazariegos, F. (1985): The use of pesticides in the cultivation of cotton in Central America. UNEP Ind. Environ., July/August/September, pp. 5-8.

Mhlanga, A.T. and J.J. Madziya (1990): Pesticide residues in Lake McLwaine. Ambio, Vol. 19, pp. 368-372.

Mitchell, D.S. and D.J.W. Rose (1979): Factors affecting fluctuations in extent of *Salvinia molesta* on Lake Kariba. PANS, Vol 25, No 2, pp. 171-177.

Muchena, P. (1988): Incidence, ecology and control of economically important crop pests in southern Africa. Strategy for integrated pest management and weed control in SADC countries. In: Summary proceedings of SADC Workshop held in Mbabane, Swaziland, August, 1988. pp. 4-13.

Munday, P.J. and M.J. Jarvis (1989): Africa's feathered locusts. Harare: Boabab Books.

Mzira, C.N. (1984) Assessment of Effects of MSV on maize yield in Zimbabwe. Zimbabwe Journal of Agricultural Research Vol. 22, pp. 141-149.

National Academy of Science (1989): Alternative agriculture. National Academy of Science, Washington, D.C.

Nhachi, C.F.B. (1988): A study of organophosphate poisoning cases at one rural and one urban hospital. Central African Journal of Medicine, Vol 34, pp. 180-188.

Nhachi, C.F.B. (1989): An evaluation of organophosphates poisoning cases in urban setting in Zimbabwe. East African Journal of Medicine, Vol 34, pp. 180-184.

Obrian, R.D. (1967): Insecticides: action and metabolism. New York: Academic Press.

OTA (1979): Pest management strategies. Vol. II. Working papers. Office of Technology Assessment, Washington, D.C.

Pimentel, D. and L. Levitan (1986): Pesticides: amounts applied and amounts reaching pests. BioScience, Vol. 36, pp. 86-91.

Pimentel, D., L. MacLaughin, A. Zepp, B.T. Lakitan, T. Krans, P. Kleinman, F.N. Vancini, E. Granp, W.S. Keeton, S. and G. Selig (1993): Environmental and economic impacts of reducing U.S. agricultural pesticide use. In: D. Pimentel and H. Lehmann (eds.): The pesticide question – environment, economics, and ethics, Chapman & Hall, New York, London, pp. 233-278.

Pope, G.G. and A. Ward (1972): The effects of small applications of organophosphate poisons, fenitriothion on the weaver-bird *Quelea quelea*. Pesticide Science, Vol. 3, pp. 197-205.

Rabbinge, R., S.A. Ward and H.H. van Laar (1989): Simulation and systems management in crop protection. Centre for Agricultural Publishing and Documentation (Pudoc), Wageningen, The Netherlands.

Rothwell, A. (1983): A revised ist of plant diseases occurring in Zimbabwe. Kirkia, Vol. 2, pp. 233-251.

Rukuni, M. (1994): The evolution of agricultural policy 1890-1990. In: M. Rukuni and C.K. Eicher (eds., 1995). Zimbabwes' agricultural revolution. Harare: University of Zimbabwe Publication Press.

Rukuni, M. and C.K. Eicher (1994): Zimbabwe's agricultural revolution. Harare: University of Zimbabwe Publication.

Sithole, S.Z. (1990): Status and control of the Stemborer *Chilo partellus*, Swinhole (Lepidoptera: Pyralidae) in Southern Africa. Insect Science Appl., Vol 11, pp. 481-488.

Sithole, S.Z. (1988): A Review of yield losses and damage caused by maize stemborers in Eastern, Central and Southern Africa. In: Crop protection for small scale farms in East, and Central Africa. A Review, Commonwealth Science Council, UK. pp. 73-87.

Sithole, S.Z. and G.P. Chikwenhere (1994): Integrated pest management in Zimbabwe: IPM implementation workshop for East, Central and Southern Africa. In: Summary proceedings of a workshop held in Harare, Zimbabwe 1993. Chatham, U.K. NRI (Natural Resources Institute). pp.83-87

Talbort, J.N. (1977): On the Dichiwe Lomon Forest and its aviafauna. Honeyguide, Vol. 89, pp. 11-35.

Thomas, P.A. and P.M. Room (1986): Taxonomy and control of *Salvinia molesta*. Nature, Vol. 320, No. 6063, pp. 581-584.

Van Rooyen, C. and D.C. Lourens (1958): Preliminary investigations of the chemical and biological aspects of the use of parathion in the eradication of *Quelea quelea lathamii*. South African Journal of Science.

Wessel, C. L., J. Tannock, D. Blake and R.J. Phelps (1980): Chlorinated hydrocarbon insecticide residues in crocodiles (*Niloticus laurentis*) eggs from Lake Kariba. Transactions of the Zimbabwe Scientific Association, Vol. 60, No. 3, pp. 11-17.

Weinman, H. (1972): Agricultural research and development in Southern Rhodesia 1890-1923. Occasional paper no 4. University College of Rhodesia.

Weinman, H. (1975): Agricultural research and development in Rhodesia 1924-1950. Series in Science no 2. University College of Rhodesia.

Wison, P. (1996): Biological control of horticultural pests. Seminar paper on biological control of weeds. Crop Science Department, University of Zimbabwe. March 13, 1996. pp. 1-4.

Annex 1-1: Details of armyworm outbreak (Spodoptera exempta Wlk.) in Zimbabwe since 1909.

Year	Party of country wide	Affected area (ha)	Damage level	Control
1909-10	Harare, Mutare	23 000	severe	
1914-15	Chegutu, Mazowe, Lomangundi, Mutare, Harare	40 000	severe	-
1920-21	Kwekwe, Harare, Mvuma, Gweru, Balabala	37 000	severe	-
1925-26	Shamva, Mazowe, Chinhoyi, Harare, Kadoma, Headlands, Chegutu, Rusape	28 700	severe	-
1926-27	Masvingo, Insiza,	12 000	severe	-
1928-29	Kadoma, Shamva, Bindura, Concession, Chinhoyi, Harare, Insiza, Filabusi, Mhondoro	15 000	severe	-
1929-30	Lomangundi, Mazowe, Harare, Enterprise, Marondera, Headlands, Rusape, Nyazura, Mutare, Norton, Chegutu, Kadoma, Gweru, Masvingo	35 000	the most severe and worst outbreak	-
1981	countrywide, but mostly in the southern part	26 000	severe	-
1982	country wide	12 000	moderate	-
1984/85	country wide	18 000	severe	chemical
1986	country wide	20 000	severe	carbaryl
1987/88	country wide	7 329	severe	carbaryl
1992/93	country wide	80 8320	severe up to 100%	carbaryl
1994/95	country wide except certain parts of the south	21 4200	severe up to 100%	carbaryl plus fenitrothion 60 EC

Annex 1-2: Some of the major pests of crops (in order of importance) in Zimbabwe

1. Maize (*Zea mays*) Maize stalk-borer (*Busseola fusca* Fuller) Spotted stem borer (*Chilo patellus* Swinhoe) Pink stem borer (*Sesamia calamistis* Hamps) Armoured ground crickets (*Acanthoplus amastiventis, Acanthoplus speiries* and *Enyaliopsis petersi*) Termites (*Hodotermes mossambiscus* Hagen and *Microtermes* spp.) Cutworms (*Agrotis* spp.) Leaf hopper for maize streak virus (*Cicadulina mbila* Naudi) Maize aphid (*Aphis sorghi*) Elephant grasshopper (*Zonocerus elegans* Thun) African armyworm (*Spodoptera exempta* Wlk.) Root lesion nematodes (*Pratylenches zeae* and *Pratylenchus Brachyurus*) Reniform nematode (*Rotylenchulus parvus*)
2. Wheat (Triticum aestivum L.) Quelea (*Quelea quelea* L.) African armyworm (*Spotoptera exempta* Wlk.) Wheat aphids [*Macrosiphum avanae* (F)] Seed corn maggot (*Hylemya cilicrura* Rand)
3. Sorghum (*Sorghum bicolor* (L.) Moench) Stalk borers (as for maize) Quelea (*Quelea quelea* L.) Doves Sorghum aphid (*Aphis sorghi)* Maize aphid (*Rhopalosiphum maidis* Fitch) Amoured ground crickets (as for maize)
4. Pearl millet (*Panicum typhoides* (Burm. f) Stapf & Hubbard) Stem borer (as for maize) Quelea (*Quelea quelea* as for wheat) Doves Sorghum aphid (as for sorghum) Maize aphid (as for maize) Armoured ground crickets (as for maize) Termites (as for maize)
5. Cotton (Gossypium hirsutum) American bollworm (*Helicoverpa armigera* Hubn) Pink bollworm (*Platyedra gossypiella* Sound) Spiny bollworm (*Earias biplaga* Wlk.) Jassids (*Empoasca fascialis* Jacobi) Red spider mite (*Tetranychus* spp.) Cotton strainers (*Dysdercus fascitus* (Stal) and *Dysdercus intermedius* Distant) Cotton aphid (*Aphis gossypi* Glov.) White fly (*Bemisia tabaci* Genn.)
6. Groundnuts (*Arachis hypogaea* L.) Groundnut hopper (*Hilda patruelis* Stal) Groundnut aphids (*Aphis craccivora* Koch) Blister beetles (*Mylabris* spp.) Termites (as for maize) White grubs (as for maize)

7. Soyabean [*Glycine max* (L.) Merrill] Semi-looper caterpillars (*Thysanoplusia orichalcea*, *Chynsodeixis acuta, Chysodeixis chalcites)* Rootnot nematode (*Meloidogyne incognita*) American bollworm (*Helicoverpa armigera* Hubner) Cutworms (*Agrotis segetum*) Aphid (*Aphis craccivora* Koch) Nematodes (*Meloidogyne javanica, Pratylenchus* spp)
8. Tobacco (Nicotiana tabacum L.) Nematodes (Root not nematode) (*Meloidogyne javanica*) Cutworms *(*Agrostis* spp.) Budworm (*Helicoverpa armigera* Hubner) Red spider mite (*Tetranychus urticae* Koch.)
9. Tomato (Lyscopersicon esculntum Mill) Red spider mite (*Tetranychus urticae* Koch.) Bollworms (*Heliothis amigera* Hubner) Nematodes (*Meloidogyne* spp. Onions (*Allium cepa* L.) Thrips Cutworms *(*Agrostis* spp) Leaf miner Nematodes (*Meloidogyne* spp.)
10. Potatoes (Solanum tuberosum L.) Potato tuber moth (*Phthorimaea operculella* Zeller) Cutworms (*Agrotis* spp.) Rootnot nematode (*Meloidogyne javanica*) White grubs (*Eulepida mashona* Arrow) Potato leaf hopper
11. Cabbage (*Brasicca* spp.) Diamond back moth (*Plutella xylostella* L.) Klebworm (*Hellula undalis* F.) Red spider mite (*Tetranychus* spp)
12. Coffee (Coffea arabica L.) Coffee leaf-miner (*Leucoptera meyricki* Ghesq.) Jelly grub (*Niphadolepis alianta* Karsch) Blackborer (*Apate monachus* Fabr.) White borer (*Anthores leuconotus* Pasc.) Dusty brown surface beetle (*Gonocephalum simplex* F.) Root mealy bug (*Planococcus citri* Risso) Creen scale (*Coccus* spp.) White grun (*Eulepida* spp.) Cotton looper (*Chrysodeixis chalcites* Esp.)

Annex 1-3: Some of the major diseases which occur in crops grown in Zimbabwe

Maize (*Zea mays* L.) Cobrots Fusarium kernel rot (*Fusarium moniliforme*) Gibberella rot (*Gibberella zeae* Schw.) Maize streak virus (*Cicadulina spp*) Grey leaf spot (*Cercospora zeae-maydi*)	**Wheat (Triticum aestivum L.)** Stem rust (*Puccinia graminis tritici* Pers.) Leaf rust (*Puccinia recondita* Rob.ex Desm.) Streak virus (*Cicadulina* spp.) Loose smut (*Ustilago nuda* (Jens) Lagert.)
Sorghum [*Sorghum bicolor* (L.) Moench] Anthracnose (*Colletotrichum graminicolum* Wils) Leaf blight (*Exserolilum turcicum* Pass) Honey dew disease (*Sphacelia sorghi* McRae) Smut [*Sphacelotheca* ceuenta (Kuhn) Potter]	**Barley (Hordeum vulgare)** Loose smut (*Ustilago nuda* (Jens.)Rostr.) Covered smut [*Ustilago hordei* (Pers.) Largert] Powdery mildew (*Erysiphe gramnis* DC.) Brown rust (*Puccinia hordei* Otth.)
Oats (Avena sativa L.) Crown rust (*Puccinia coronata* Corda) Loose smut [*Ustilago avenae (Pers) Rostr.]*) Stem rust (*Puccinia graminis* var. *Avenae* Pers.)	**Pearl millet (Pennisetum typhoides)** Green ear (Downy mildew) (*Sclerospora graminicola* sacc.) Smut (*Tolyposporium penicillariae* Bref Honey dew (*Sphacelia sorghi* McRae) Ergot (*Claviceps microcephala* Waller) Rust (*Puccinia penniseti* Zimm)
Groundnuts (Arachis hypogaea L.) Cercospora leaf spot (*Cercospora arachidicola*) Phoma web blotch (*Phoma arachidicola*) Rust (*Puccinia arachidis* Speg) Grey mould (*Botrytio cinerea* Pers.ex Fr.)	**Onions (Allium cepa L.)** Purple blotch (*Alternria porri (Ell.) Gf.*) Downymildew (*Peronospora destructor* (Berk.) Casp) White rot (*Sclerotium cepionum* Berk.)
Potatoes Solanum tuberosum L.) Late blight [*Phytophthora infestants* (Mont.) deBary] Early blight (*Alternaria solani* Sorauer) Common scab (*Streptomyces scabies* Thaxt) Bacterial wilt (*Pseudomonas solanaceanum* E. F. Sm) Powdery mildew (*Erysiphe cichoraceanum* DC.) Powdery scab [*Spongospora subterranea* (Waller) Lagerh]	**Cotton (Gossypium hirsutum L.)** Bacterial wilt (*Xanthomona malvacearum* E.F. Sm) Fusarium wilt (*Fusarium oxysporum* Schlecht.) verticilium wilt (*Verticilium alboatrum* Reinke & Berth)
Soyabean [Gylcine max (L.) Merrill] Red leaf blotch (Pyremochaeta glycines Stewart) Bacterial blight (*Pseudomonas syringae* pv *glycinea* Coerper) Purple seed stain (*Cercospora kirkuchii* T. Matsu and Tomoyasa)	**Tobacco** Alternaria (*Alternaria solani* Sofauer) Anthracnose *Colletotrichun tabacum* Bonning) Fusarium wilt (*Fusarium oxysporum* Schlecht.ex Fr.f. sp. *nicotianae* Synd. and Hans)
Tomatoes and Paprika Early blight (*Alternaria solani* Sorauer) Late blight (*Phytophthora infestants* Mont deBary) Bacterial spot [*Xanthomonas campestris* pv. *Vesicatoria* (Doidge) Dawson] Bacterial speck (Pseudomonas syringae pv. Tomato	**Cabbage, rape and kale** Black rot [*Xanthomonas campestris* (Pamenel) Dawson] Damping off (*Pythium ultimum* Trow) (*Rhizoctonia solani* Kuhn) Downy mildew (*Peronospora parasitica* Pers.ex.Fr) Tul) Clubroot (*Plasmodiophors brassicae*)

Annex 1-4: Some of the major weeds which are problematic in field crops and other environments

Grasses Shamva grass (*Rottboellia cochincinesis* (Lour) W.D. Clayton Rapoko grass (*Eleusine indica* L.) Couch grass (*Cynodon dactylon* (L.) Pers.)	**Sedges** (1) Yellow nutgrass (*Cyperus esculentus* (L.) (2) Purple nutsedege (*Cyperus rotundus* (L.)
Broadleaf Wandering jew (*Commelina benghalensis* L.) Fat hen (*Chenopodium album* L.) Gallant soldier (*Galinsoga parviflora* Cav.) Sow thistle (*Sonchus oleraceus* L.) Pigweed (*Amaranthus hybridus* L.) Apple of peru (*Nicandra physalodes* (L.) Gaertn.) Mexican clover (*Richardia scabra* L.) Upright starbur (*Acanthospermum hispidum* DC) Blackjack (*Bidens pilosa* L.) Lantana (*Lantana camara* L.) Portulaca (*Portulaca oleracea* L.)	**Parasitic** Witchweeds *Striga asiatica* L. Kuntze *Alectra vogelli* Benth **Aquatic weeds** Water hyacinth (*Echhornia crasippes* (Mart.) Solms) Water lettuce (*Pistia stratiotes* L.) Azolla (*Azolla filiculoides*) Kariba weed (*Salvinia molesta*)

Annex 1-5: Area covered of *Salvinia molesta* on Lake Kariba

	Area under *S. molesta* (km^2)		Percentages of lake covered
Date	Whole lake	South lake	
April 1960	286	165	11.5
August 1960	421	261	13.7
March 1961	580	366	17.5
August 1961	724	500	18.0
May 1962	1003	553	21.5
April 1963	795	455	14.8
March 1964	529	330	10.7
May 1965	651	385	12.4
June 1967	823	480	16.1
May 1971	-	375	±15.0
August 1972	-	-	±15.0
August 1973	-	77	5.0
August 1974	-	94	5.0
May 1975	-	79	5.0
August 1976	-	39	3.0

Source: MITCHELL and ROSE 1979 (modified)

Annex 1-6: Some of the non-target organisms killed in quelea control operations

Species	Area Number of organisms	
	Bindura	Dichwe
African water Rail (*Rallus caerulescens)*		2
Black Crake (*Amaurornis flavirostris)*		6
Common Moorhen (*Gallunula chloropus)*		1
Painted Snipe (*Rostratula benghalensis)*		4
Red-faced Mousebird (*Colius indicus)*		11
Pygmy Kingfisher *(Ceyx picta)*	1	
Brown-hooded Kingfisher (*Halcyon albiventris)*		3
Little Bee-eater (*Merops pusillus)*	1	2
Black-collared Barbet (*Lybius torquatus)*		1
Crested Barber (*Trachphonus vaillanti)*		2
Fork-tailed Drongo (*Dicrurus adsimilis)*	4	1
Black-eyed Bulbul *Pycnonotus barbatus)*	1	2
Yellow-bellied Bulbul (*Chlorocichla flaviventris)*		2
Terrestrial bulbul (*Phyllastresphus terrestris)*		2
Heuglin's Robin (*Cossypha heuglini)*		4
White-browed Scrub Robin (*Erythropygia leucophrys)*		1
Reed Warbler (*Acrocephalus baeticatus)*	3	
Lesser Swamp Warbler (*Acrecephalus gracilirostris)*		6
Little Rush Warbler (*Bradypterus baboecala)*	3	
Yellow-breasted Apalis (*Apalis flavida)*	1	1
Yellow-bellied Eremomela (*Eremomela icteropygialis)*	1	
Bleating Bush Warbler (*Camaroptera brachyura)*		2
Rattling Cisticola (*Cisticola chiniana)*		2
Tawny-flanked (*Prinia subflava)*		1
White-flanked Batis (*Baris molitor)*		1
Yellow-throated Longclaw (*Macronyx croceus)*		5
Southern Puffback (*Dryoscopus cubla)*	1	2
Brubru (*Nilaus afer)*	1	
Brown-headed (*Tchagra australis)*		1
Purple-banded Sunbird (*Nectarinia bifasciatva)*		3
White-bellied Sunbird (*Nectarinia talatala)*		3
Scarlet-chested (*Sunbird senegalensis)*	1	1
White-eye (*Zosterops senegalensis)*	1	
Spotted-backed Weaver (*Ploceus cucullatus)*	12	42
Masked Weaver (*Ploceus velatus)*		9
Large Golden Weaver (*Ploceus xanthops)*		1
Red Bishop (*Euplectes orix)*		1
White-winged Whydah (*Euplectus albonotatus)*	16	13
Red-throated Twinspot (*Hypargos niveoguttatus)*	3	
Blue Waxbill (*Uraeginthus angolensis)*		5
Orange Waxbill (*Amandava subflava)*	5	
Yellow-eyed Canary (*Serinus mozambicus)*	1	1

Source: Modified from TALBOT (1977).

2 Pest Management and Pesticide Use Research in Zimbabwe

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Abstract

The paper defines the term pesticide, classifies pesticides according to field of use and degree of toxicity and gives the range used in Zimbabwe. It highlights the pesticide registration scheme and the importance of research in the development and utilization of pesticides. Various acts of Parliament Acts and regulations governing plant protection are described and several pest control methods are given including environmentally friendly strategies. The commercial farming sector, especially horticultural industry, is the main user of pesticides in pest and disease control for the realization of high yields and quality produce. The small-scale and communal sectors show less reliance on pesticides in pest management. Over a period of 15 years there has been a concomitant increase in pesticide utilization by all farming sectors with increase in the economic importance of tobacco, cotton, coffee, soybean and maize.

The paper describes fourteen public and private institutions researching on pesticide efficacy and utilization, and identifies research priorities. International organizations collaborating with national research institutions are covered including specific areas of cooperation in pest management.

2.1 Introduction

The main goal of pest management research is to contribute towards improved and sustainable human health care, animal and crop production systems by reducing the impact of health factors, animal and crop losses due to diseases, insect and mite pests, nematodes, vertebrate pests and weeds.

Crop cultivation practices in Zimbabwe are shifting from small- to large-scale farming with increased use of water for irrigation. Irrigation water increases atmospheric humidity and therefore, making environmental conditions more favorable for pest multiplication (SITHOLE and CHIKWENHERE, 1994). Farmers'

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options in pest management strategies may be categorized into chemical and non-chemical control measures.

Commercial farmers use various chemical pesticides to control pests while communal farmers are generally limited to non-chemical strategies except in controlling pests of cash crops such as cotton. However, communal farmers include pesticides in their pest management strategies whenever outbreaks occur.

The majority of vegetable growers in the commercial farming sector often apply pesticides as soon as they observe the presence of pests in the field without considering the cost-effectiveness of such applications probably because of their preconceived desire for instant results. This may be ascribed to absence of information on threshold levels as decision-making tools for pesticide applications. Clearly, it is essential that threshold levels are established through research and development for effective pesticide utilization. The agricultural sector has expanded tremendously since Zimbabwe's attainment of independence in 1980. The 1980-95 period witnessed an increase in the economic importance of tobacco, cotton, maize, coffee, soybean, groundnuts, cutflowers, fruits and vegetables as major earners of foreign currency. Parallel to expansion in agricultural production has been increased the economic importance of human, animal and plant pests.

Dependence on intensive use of pesticides by the commercial farming sector ensures realization of high yields and quality produce. Horticulture is increasingly becoming an important earner of foreign currency amounting to approximately above ZW$ 600 million. The horticultural industry is heavily dependent on the use of pesticides because non-chemical measures cannot control pests adequately. Although non-chemical pest control methods such as biological control and use of resistant varieties have proved effective, the use of pesticides will continue to play an important role in minimizing risks to human beings, animals and plants due to pests. The role of pesticides in increasing agricultural production and maintenance of public and animal health standards is indisputable. Zimbabwe is currently shifting towards an integrated approach to pest management (IPM) to ensure sustainable environmental safety by reducing the number of pesticide applications as the use of pesticides is increasing.

2.2 Definition

A pesticide may be defined as a substance or a mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal diseases, unwanted species of plants or animals causing harm during or otherwise interfering with the production or processing, storage, transport, or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term pesticide includes substances intended for use as a plant growth regulator, defoliant, desiccant, or agent for thinning fruit or preventing the premature fall of fruit and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. Although pesticides were once celebrated as rescuers of harvests threatened by pests and diseases, today they are criticized as a burden to the environment and risk to humans and non-target organisms. The question that may be asked is what tomorrow's crop protection will be like. Human, animal and crop protection experts take pride in many milestones attained from research and expect a future characterized by confidence and initiative. Thanks to pesticides, farmers no longer have fear on the quality and quantity of their crops and animals and their health. However, efficacy, environmental concerns and commercial viability are equally important criteria on which pesticides of tomorrow will be judged. Therefore, research efforts into pesticide use will continue to be a challenge to mankind.

Pesticides may be classified according to the field in which they are used to control pests. These categories are:

1. **Agricultural pesticides** used in agriculture, horticulture and forestry to control field stored product pests. Pesticides and animal remedies for the control of veterinary pests and disease are included in this category.
2. **Household pesticides** employed in the control of household pests. These include household sprays, aerosols, insect coils, smoke generators and rodenticides.
3. **Public health pesticides** include all pesticides used in public health programs.
4. **Industrial pesticides** used in the industry like wood preservatives, pesticides in paints and anti-fouling agents.

Zimbabwe employs several methods in crop pest management (SITHOLE and CHIKWENHERE, 1994). These include :

1. Chemical control
2. Cultural control
    - Crop rotation
    - Inter- and mixed cropping
    - Field sanitation/weeding
    - Closed season when possible
    - Tillage operations
    - Planting and harvesting dates
    - Spacing
    - Seed rates
    - Plant populations
    - Fertilization
    - other crop husbandry practices
3. Biological control
4. Host-plant resistance
5. Integrated pest management
6. Plant Quarantine and legislation
7. Use of pheromone traps to monitor pests

2.3 Research institutions

The various public and private institutions involved in pesticide research include:

1. **Plant Protection Research Institute (PPRI)** of the Department of Research and Specialist Services (DR & SS) in the Ministry of Agriculture is the public sector institution responsible for the registration of crop and household pesticides and research into pest management strategies including evaluations of efficacy data of candidate pesticides prior to registration. The research may be done by PPRI officers on their own or in collaboration with other research organizations in the country such as agro-chemical companies. The Institute is the overall authority responsible for evaluation of efficacy data prior to registration.

2. **Cotton Research Institute (CRI)**, one of the institutes of DR & SS, conducts research on the management of cotton pests, evaluates efficacy data from other institutions and submits efficacy recommendations to the pesticide registering office (PPRI).

3. **Weed Research Team (WRT)**, under Agronomy Institute, conducts research into weed management and is involved in the evaluation of efficacy data generated by other research institutions such as agro-chemical companies, Tobacco Research Board and CRI. After commenting on candidate herbicide efficacy data the team submits recommendations on registration to pesticide registering office (PPRI).
4. **Chemistry and Soil Research Institute (CSRI)** is involved in carrying out chemical analysis of candidate pesticides at the request of PPRI (Pesticide Registering Authority) or agro-chemical companies wishing to register pesticides. The chemical analysis is a verification of the active ingredient of a product from a new source and is compared with a standard sample from a known source. This activity aims at maintaining standards of pesticide formulations by avoiding registration of pesticides with impurities. CSRI is also responsible for carrying out pesticide analysis at the request of various research institutions.
5. **Department of Veterinary Services (DVS)** is responsible for registration of pesticides for the control of pests of veterinary importance. The **Tsetse Research Team (TRT)** of DVS researches into the management of tsetse flies. It conducts pesticide research to generate efficacy data in collaboration with agro-chemical companies or at the Department's own initiative. However, the data generated can only be submitted by agro-chemical companies concerned for registration purposes because the Department is the registering authority for veterinary pesticides.
6. **Blair Research Laboratory (BRL)** of the Ministry of Health and Child Welfare conducts research on the use of pesticides in the management of household pests including mosquitoes, cockroaches, houseflies and rodents. The data generated is used by agro-chemical companies in applying for pesticide registration. Research is conducted at the initiation of the Laboratory's officers themselves or on request by agro-chemical companies wishing to register pesticides for the control of household pests.
7. **Government Analyst Laboratory (GAL)** in the Ministry of Health and Child Welfare is involved in the verification of chemical analysis of candidate pesticides whenever requested by agro-chemical companies applying for pesticide registration. This institution is also involved in conducting pollution studies in the field.

8. **Problem Bird Control Unit (PBCU)** under the Department of National Parks and Wildlife Management in the Ministry of Environment and Tourism is responsible for generating efficacy data for avicides. The unit is responsible for controlling quelea birds causing cereal crop losses. Officers in this unit also research on the biology and ecology of this vertebrate pest of economic importance to Zimbabwe in relation to national food security.

9. **Agro-chemical Industry Association (ACIA)** is involved in pesticide formulation and conducting experiments on their efficacy, utilization and safety in the environment. This activity is achieved through member companies of the association.

10. **The Departments of Crop Science and Chemistry of the University of Zimbabwe (UZ)**, conduct efficacy trials and chemical analyses, respectively on behalf of interested agro-chemical companies. Client agro-chemical companies submit efficacy data generated to pesticide registering institutions upon applying for registration.

11. **Tobacco Research Board (TRB)** researches on the efficacy of candidate pesticides for the control of tobacco pests. It is also involved in the evaluation of efficacy data generated by other research organizations such as agro-chemical companies but the submission of data for registration purposes is left to the interested company. The board also has facilities for chemical analysis to ascertain the level of active ingredient of candidate pesticides.

12. **The Grain Marketing Board (GMB)** is involved in pesticide research related to the efficacy and safe use of grain protectants.

13. **Consultant companies** conduct efficacy trials on behalf of interested agro-chemical companies. This group comprises scientists who retired from working in registered agro-chemical institutions and government departments. The consultants submit results of efficacy trials to client companies which then submit the applications for registration to the pesticide registering authorities (PPRI).

2.4 Research areas

In Zimbabwe, pesticide research in relation to pesticide utilization includes the following areas:

1. Pesticide efficacy investigations
2. Development of optimum dosages and application intervals
3. Harvesting intervals
4. Pesticide residues

Research data must be generated prior to pesticide registration. During this process, the efficacy and safety of the candidate pesticides are evaluated in relation to benefits that could be derived from their use. Benefits are weighed against potential hazards from introducing a new chemical compound into the environment.

In Zimbabwe a prospective applicant wishing to register a pesticide approaches technical advisers before proceeding to efficacy data generation through an experimental program. Experimental details are discussed in relation to the nature of the host and pest. The applicant may elect to conduct the experiment on his own, contract a consultant or collaborates with other research institutions/organizations including the institutions responsible for pesticide registration (PPRI and DVS). A sample of the material to be registered is submitted to the pesticide registering officer for chemical analysis so that the level of active ingredient is compared with a known standard.

This is done by CSRI, GAL, UZ, TRB and other reputable laboratories in the country. An experiment on efficacy may include candidate chemical pesticides from different prospective applicants especially when conducted by a government institution like PPRI. When trials are conducted by non-government institutions, officers from the registering Government institution are often invited to assess the experiment in progress which normally takes three cropping seasons for new crop pesticides to have their efficacy confirmed prior to registration.

Huge sums of money are spent annually by agro-chemical companies in search of new products. Usually, new herbicides have a long life expectancy but new insecticides, acaricides and fungicides often encounter resistance problems within a few years of being launched for commercial use (COPPING, 1990). To remain in business an agro-chemical company needs to recoup its investment in a product and make profit to ensure later investment in a new generation of products. Clearly, all discovery products are targeted towards large markets where there are opportunities for significant sales. This explains why agro-chemical companies seek products that control weeds, diseases, insect and mite pests of maize, soybean, small grains, cotton, tobacco and coffee because of their economic importance. Once a major market has been secured for a product, the opportunities in small markets can be exploited (COPPING, 1990). No company would develop a herbicide for use in a field of sweet potatoes but would establish a market in cereals and then oil seed rape and sales in kale may well be added to the product's potential sales. Thus it is unfortunate that some products will never be registered for use in the control of pests of some crops because of the small area grown or because their low value.

2.5 Research priorities

2.5.1 Resistance of pests to pesticides

Extensive use of pesticides has often resulted in the development of pesticide resistance in insect and mite pests, plant pathogens and weeds. Clearly, this suggests mitigation research to be conducted in this aspect. Little or no research work has been done in Zimbabwe and this probably explains the absence of documentation of cases of pesticide resistance in pests. Storage insect pests are believed to be resistant to the use of malathion which is widely used as a grain protectant. Coffee insect pests are believed to be developing resistance to parathion but it has not been convincingly substantiated by researchers. Therefore, vigorous research efforts must be made in this regard. Approximately 504 insect and mite pest species, 150 plant pathogens and 273 weed species have developed resistance to pesticides (GEORGHIOU, 1990).

Increased cases of pesticide resistance by pest species may be ascribed to increased number of pesticide applications in order to sustain expected yields. The additional pesticide applications cause a problem by increasing environmental selection for resistance traits in pest species. The impact of resistance develops gradually over time and is felt in the economics of agricultural production. Like crop pests, a large number of livestock and human insect and mite pests have shown evidence of pesticide resistance. Therefore, looking into pesticide resistance in pest species is one of the priorities in pest management research.

2.5.2 Contamination of underground and surface waters

Some pesticides applied on crops find their way into ground and surface waters. Pesticides like aldicarb, alachlor and atrazine contaminate ground water (OSTEEN and SZMEDRA, 1989). These pesticides are registered for agricultural use in Zimbabwe and yet research into their impact on the environment has not been done.

There are three major concerns on these pesticides contaminating ground water. One is that the communal people rely on wells, bore-holes and rivers as sources of water for domestic use. Secondly, once ground water is contaminated, pesticide residues remain in the ecosystem for long periods of time and thus the communal population is more or less at risk on a continuous basis. The situation is made worse by the presence of very few microorganisms with the potential to degrade pesticides and the recharge is not more than 1% per year. A study of levels of contamination of ground water by pesticides is therefore essential to establish of the status of contamination and institute cleanup programs whenever necessary; a costly task (PIMENTEL et al., 1992).

2.5.3 Impact of pesticides on human health

The effect of pesticide use on human health has received little or no research attention in most developing countries including Zimbabwe. According to World Health Organization and United Nations Environmental Program (WHO/UNEP, 1989), approximately 1 million human pesticide poisoning cases occur annually in the world with about 20,000 fatalities. LATOVITZ et al. (1990) reported that about 67,000 non-fatal poisoning incidences occur each year in the United States. Little has been done in this area in Zimbabwe and information is very fragmented. Therefore, the need for research in this aspect in Zimbabwe cannot be overemphasized. Zimbabwe needs to look at acute, subacute and chronic health effects of pesticides because many acute and chronic maladies are associated with pesticide use in countries that use a lot of pesticides. For example, dibromochloropropane (DBCP) has been banned in some countries because it causes testicular dysfunction in animal studies (FOOTE et al., 1986). This is linked with infertility among workers exposed to DBCP (POTACHNIK and YANAI-INBAR, 1987). Over recent years, a large body of evidence accumulating from animal studies indicated that pesticides cause dysfunction of the immune system (THOMAS and HOUSE, 1989).

Women who chronically ingest ground water contaminated with low levels (6.6 ppb of aldicarb) show significant reduction in immune response, although they exhibit no overt health problems (FIORE et al., 1986). Currently, the greatest concerns associated with organophosphorus pesticides (OPS) which replaced organochlorines already banned from use world wide are irreversible neurological defects they cause in animals including man (LOTTI, 1984; ECOBICHON et al., 1990). Evidence from studies confirms that neurotoxic effects persist even after termination of an acute poisoning incident (ECOBICHON et al., 1990). Other documented effects are in memory, mood and abstraction. Clearly, such chronic health problems are of public health concern because people are exposed to some pesticide residues; everywhere, in food, water and atmosphere. Vegetables and fruits receive the highest dosages of pesticides and therefore residue studies in this area are imperative.

2.5.4 Impact of pesticide use on non-target organisms

In both natural and agricultural ecosystems, pest and non-pest species are adversely affected by pesticide use (CROFT, 1990). Predacious and parasitic species (non-target natural beneficial organisms) control or help control pest populations and ensure that ecosystems remain foliated (PIMENTEL et al., 1992). It is for pest species to attain outbreak levels following the destruction of their natural enemies. Examples include cotton bollworm, tobacco budworm, cotton aphid, spider mites and semi-loopers (OTA, 1979). Parasitic and predacious insects often exhibit searching and attacking behavioral patterns. Sub-lethal insecticide dosages are known to alter behavioral patterns of insects. Therefore, use of pesticides can disrupt effective biological control.

Fungicides may facilitate pest outbreaks whenever they reduce fungal pathogens that are naturally parasitic on many insects as evidenced by use of benomyl in controlling pest pathogens. Benomyl is capable of reducing populations of entomopathogenic fungi resulting in the survival of pests such as cabbage loopers in soybeans. The increased pest populations lead to reduced soybean yield (JOHNSTON et al., 1976). When outbreaks of secondary pests occur, because natural enemies are destroyed, it is common to apply expensive pesticides to ensure sustainance of crop yields and overall costs are raised. Biocontrol has been estimated to control 90% of pest species in agro-ecological systems and natural systems while 10% is ascribed to pesticides/host plant resistance and other limiting factors prevalent in the ecosystem.

2.5.5 Impact of pesticide bans on research

Although pesticides promote agricultural productivity, they can have adverse effects on the environment and human health and therefore they justify for government regulations on their importation and use (ZILBERMAN et al., 1991). Banning the use of certain pesticides constitutes a means of avoiding the use of environmentally unfriendly pesticide such as DDT, aldrin, dieldrin and methyl bromide. From time to time, registered pesticides are reviewed in terms of their efficacy, impact on lifeforms and environment. Reviews may ban or restrict the use of certain pesticides on the basis of new information arising from research on the biological and environmental properties of the product. Aldrin and dieldrin (organochlorines) have been withdrawn from pesticide registers globally because of their long persistence in the environment and adverse effects on lifeforms.

In Zimbabwe, aldrin and dieldrin have been banned for use in crop production and therefore have been removed from the pesticide register. These two pesticides were very effective in controlling soil insect pests including the difficult termites, especially in tropical zones of the world like Zimbabwe.

Zimbabwe has not conducted research on the impact of banning pesticides from use in crop production and health delivery system but the immediate effect observed is a shift towards the utilization of more expensive or less effective alternatives or both. When the differences in the cost and efficacy of the banned and alternative pesticides are small, the economic impact is small but large when the alternative is more expensive or less effective in controlling the target pest. Banning pesticides from use tends to step up research and development efforts in search of alternatives in order to mitigate the effect of the ban. A ban on the use of a pesticide reduces agricultural production as a result of crop losses due to damage caused by uncontrolled pests. Banning two or more pesticides such as those related to inducing cancer or causing damage to reproductive system at the same time reduces the chances of getting alternatives and decreases crop yields more than banning one from use (ZILBERMAN et al., 1991). Some negative impacts of banning pesticides may be mitigated by new technologies. Increases in the prices of alternatives spur more research and development of less expensive pesticides.

2.5.6 Search for alternatives / replacements

Aldrin and dieldrin effectively controlled the destructive black maize beetle in sugarcane plantations in Zimbabwe. Since their ban from agricultural use, there has been an upsurge in pest populations they used to control before the ban. This can only be ascribed to failure by researchers to come up with suitable alternative or replacement pesticides. In the absence of a breakthrough, research efforts have to be doubled, although currently there is no hope of finding replacements as cost-effective as the two organochlorines.

Currently, the greatest global concern is the use of methyl bromide, a broad-spectrum pesticide with insecticidal, nematicidal, fungicidal, bactericidal and molluscicidal properties. It is a small molecular and gaseous fumigant used in the following processes (SCHONFIELD et al., 1994):

1. **Soil fumigation:** Methyl bromide is used to kill pest species in the soil prior to planting tobacco and horticultural crops. It is injected into the soil covered by plastic trap to contain pests.
2. **Fumigation of perishable goods:** It kills pests on or in food and other exported products either at the point of export or import. Fumigation with methyl bromide is often a requirement by importing countries.
3. **Fumigation of durable goods:** Methyl bromide is used to control pests on or in timber wood products, dried spices and large volumes of grain such as maize, wheat and rice.
4. **Fumigation of structures:** It has use in controlling pests (e.g. termites) of building structures.

Methyl bromide has been identified as one of the ozone depleting substances and as a result there is a global outcry for it to be phased out by the year 2001. Owing to this outcry, Zimbabwe and other countries using methyl bromide as a pesticide have the great task of searching for alternatives which could be chemical pesticides, biopesticides, cultural, biological and other pest control measures which are environmentally friendly. Perhaps this explains why currently there is a global drive to promote an integrated approach to pest management. Clearly, Zimbabwe has recognized the need to conduct research into integrated pest management with the possibility of making it the major national plant protection strategy.

2.6 Integrated pest management (IPM)

The damages of the continued and indiscriminate use of pesticides in the management of pests have become apparent to the farming, extension, research and administrative communities of Zimbabwe. Therefore, in recent years, there has been renewed interest in the development and application of alternative methods, which are cost effective, efficient and environmentally friendly and sustainable.

In this respect, IPM systems offer a viable option. IPM is a relatively new comprehensive approach in reducing crop losses due to pests, diseases and weeds. It owes its name to the fact that it unites several preventive and curative measures and integrates them into agricultural systems, (crop rotation, intercropping, genetic resistance etc.). Pesticides are used as little as possible as a last resort.

Potato

Owing to indiscriminate use of pesticides by some farmers on potato fields, the Potato Tuber Moth (PTM) was reported as a major potato pest in some parts of Zimbabwe during the period of 1978 to 1987 particularly in the Midlands Province. Laboratory bred *copidosoma* populations were released further afield and since then the pest has been brought under control.

Cotton

The Cotton Research Institute of the DR & SS, has been practicing IPM on major cotton pests. Pest scouting and pesticide rotation scheme have been put into practice. Insecticides toxic to the larvae of chrysopids or green lacewings namely *Chrysops bonniness, C. cogrua and C. pudica,* especially those commercially used against aphids and other major cotton pests have been screened.

Coffee

In 1986 a law was enacted to regulate the movement of coffee plants including seeds from Coffee Berry Disease (*Colletotrichum coffeanum)* infested areas to avoid its spread to the Eastern Highlands, the major coffee growing area of Zimbabwe.

Tobacco

IPM in tobacco is an on-going program conducted by Tobacco Research Board (TRB) for the benefit of both small and large scale tobacco growers. It includes: regulations on growing and destruction of tobacco stalks during stipulated time periods to keep pests and pathogens below economic threshold levels, restrictions on the use of pesticides, crop rotations, judicious use of fertilizers, ridging, use of resistant cultivars of tobacco against pests and pathogens, biological control of sore- shin complex with the use of *Tricoderma spp*. and finally curing and storage management.

Strawberries and hops

In 1990, a commercial horticultural company (HORTICO) imported *Phytoseiulus persimilis* to control the Two spotted Mite (*Tetranychus urticae*) which is a serious pest of strawberries and hops in Zimbabwe. Post-release monitoring of the above phytoseid is underway. The company is also looking into the possibility of using two fungi (*Beuvaria bassina* and *Verticillium lecanii*) against thrips (*Thrips tabaci)* on other horticulture crops.

Water lettuce and water hyacinth

Water lettuce or Nile cabbage (*Pistia stratiotes L)* reached critical proportion in various water bodies including Manyame River system, Lake Chivero (formerly McIlwaine), Chakoma, Chivake and Kaitano Dams, Seke and Manyame (formerly Prince Edward and Darwendale, respectively) Dams, Lake Kariba and its tributaries Gachegache and Sanyati rivers between 1986 and 1990.

In 1988 the weevil (*Neohydronomus affinis*) imported from Australia was introduced at sites on Manyame River system to control *Pistia stratiotes* infestations. In less than 12 months after initial releases, *N. affinis* reduced thick mats of water lettuce to insignificant levels.

Water hyacinth *(Eichhornia crassipes*) was first recorded in Zimbabwe in 1930 and it has been periodically a major problem in Lake Chivero since the 1950s.

Mechanical control of this weed proved ineffective and success has only been achieved by chemical control with 2,4-D. In order to contain this menace, biological control agents, *Neochetina eichhorniae* and *N. bruchi* were released at Lake Chivero in January, 1990 and are now well established. The effectiveness of biological control of water hyacinth has been hampered by intensive chemical herbicide campaign which began in February 1991. Since August 1990 more than ZW$ 10,000,000 have been spent to control *E. crassipes* by mechanical and chemical means. An integrated approach to the water hyacinth problem has already been recommended and is in progress.

Lantana camara

An attempt to control *Lantana camara* by means of introduced insects was made in Zimbabwe in 1962. This was unsuccessful for a variety of reasons, one of which was that there are different *Lantana* races and insects appear to be race-specific. The insects that were introduced from Zambia were a bug (*Teleonemaia scrupulosa*) and caterpillar (*Syngania sp*.). No research has been done to determine *Lantana camara* races, the extent of the problem, introduction of mass race specific natural enemies and study of the adaptability of natural enemies under local environment.

Biological control of plant parasitic nematodes

Investigations are underway on the biological control of root knot nematode (*Meloidogyne spp*.) using a fungus *Pausterialis penetrans* on tomato long with soil amendments with neem leaves, neem oil and Syringia bean powder. Attempts are also being made to develop technology to control lesion nematode *(Pratylenchus sp*.) on maize with the use of soil amendments.

Production of virus free plant material

Tissue Culture Laboratory in the Department of Crop Science at University of Zimbabwe has successfully developed virus free material of potato, (*Solanum tuberosum*), sweet potato (*Ipomea batatus)* and cassava (*Manihot esculanta*) and is in the process of distributing the material to farmers. Similarly, a virology laboratory at Plant Protection Research Institute, has set up plant virus diagnosis facility, thus positively contributing towards future plant virus control component of IPM.

In spite of the significant developments and progress in the field of IPM in selected crops in Zimbabwe, it is apparent that there is no coordinated program on IPM in the country. Most of the research and technology development exclusively deals with biological control of pests and pathogens. At the same time, very little, if any benefit has reached the peasant farming sector.

2.7 Collaboration with international research organizations and institutions

Joint collaborative research projects on pest management have been formulated by Plant Protection Research Institute and international research organizations / institutions such as FAO, DANIDA, NRI, GTZ including CGIAR centers such as CIMMYT, IITA, ICRISAT and ICIPE. Projects under implementation include the following:

- **GTZ-IITA:** Biological control of plant pests (aquatic weeds, maize and sorghum stemborers), survey of indigenous parasitoids.

- **GTZ-IPM Horticulture:** Biological control of diamondback moth in cabbage, of mites using predatory mites and of root-knot nematodes.

- **DANIDA:** Strengthening of Plant Quarantine and Inspection Services:
  - Construction and establishment of plant quarantine station at Mazowe.
  - Construction of staff houses at Mazowe Plant Quarantine Station.
  - Supply of equipment and laboratory chemicals.
  - Providing vehicles for use during plant inspection duties.
  - Training of staff in country and abroad.
  - Seed Pathology Satellite Centre (SPSC) of the Danish Government Institute of Seed Pathology (DGISP) for Africa located in Zimbabwe. This is a regional center whose objectives include the Immediate field oriented training of personnel involved in seed health testing, plant quarantine and chemical control of seed-borne diseases, and field demonstration on the beneficial aspects of using healthy seed to extensionists and farmers.

- **Natural Resources Institute (NRI):** Minimization of on-farm storage losses due to pests and diseases with particular reference to the Larger Grain Borer (*Prostephanus truncatus*). Small-scale and communal farming sectors are the target because they will be unable to afford the cost of controlling the pest using pesticides. The project advocates the use of an integrated approach to the management of this pest so that pesticides are used only as an intervention.

- **CIMMYT:** Mass rearing of cereal stemborers for field artificial infestation in a program on screening maize germplasm for resistance to stemborers. The project also involves a survey of indigenous natural enemies of maize stemborers.

- **ICRISAT:** Assessment of losses in sorghum due to stemborers and economic analysis of pesticide use in the management of stemborers.

- **ICIPE:** A survey on the distribution of whitefly and indigenous parasitoids of cereal stemborers.

- **FAO:** Development and implementation of IPM in cotton production in Zimbabwe. This is a pilot project with the objectives of reducing the number of pesticide applications in cotton production and sensitizing the smallholder farming sector in the principles of Integrated Production and Pest Management (IPPM). It is hoped that IPM will be adopted by Zimbabwe as the main pest management strategy.

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References

Copping, L.G. (1990): Aspects of pesticide discovery. pp. 16-26.

Croft, B.A. (1990): Arthropod biological control agents and pesticide. New York: John Wiley & Sons.

Ecobichon, D.J., J.E. Davis, J. Doule, M. Ehrich, R. Joy, D. McMillian, R. MacPhail, L.W. Reiter, W. Slikker and H. Tilson (1990): Neurotoxic effects of pesticides. In: C.F. Wilkinson and S.R. Baker (eds.): The effect of pesticides on human health, Princeton, N.J.: Princeton Scientific Public. pp. 131-199.

Fiore, M.C., H.A. Anderson, R. Hong, R. Golubjatnikov, J.E. Seiser, D. Nordstrom, L. Hanrahan and D. Belluck (1986): Chronic exposure to Aldicarb-contaminated groundwater and human immune function. Environ. Res., Vol. 41, pp. 633-645.

Foote, R.H., E.C. Schermerhorn and M.E. Simkin (1986): Measurement of semen quality, fertility, and reproductive hormones to assess dibromochloropropane (DBCP) effects in live rabbits. Fundamental. Applied. Toxicology, Vol. 6, pp. 628-637.

Georghiou, G.P. (1990): Overview of insecticide resistance. In: M.B. Green, H.M. LeBaron and W.K. Moberg (eds.): Managing resistance to agrochemicals from fundamental research to practical strategies. American Chemical Society. Washington, DC. pp.18-41.

Johnson, D.W., L.P. Kish and G.E. Allen (1976): Field evaluation of selected pesticides on the natural development of entomopathogen, *Nomuraea rileyi*, on the velvetbean caterpillar in soyabean. Environmental Entomology, Vol. 5, pp. 964-966.

Keeling, J.W., R.W. Lloyd and J.R. Abernathy (1989): Rotational crops response to repeated application of korflurzon. Weed Technol., Vol. 3, pp. 122-125.

Latovitz, T.L., B.F. Schmitz and K.M. Bailey (1990): 1989 Annual report of the American Association of Poison Control of Centres National Data Collection System. Am. J. Emerg. Med. Vol. 8, pp. 394-442.

Lotti, M. (1984): The delayed polyneuropathy caused by some organophosphorus ester. In: C. L. Galli, L. Manzo and P.S. Spencer (eds.): Recent advances in nervous systems toxicology. New York: Plenum. pp. 247-257.

McEwen, F.L. and G.R. Stephenson (1979): The use and significance of pesticides in the environment. New York: John Wiley & Sons.

Office of Technology Assessment (OTA) (1990): Pest management strategies. Congress of the United States, OTA, Washington, DC.

Osteen, C.D. and P.I. Szmedra (1989): Agricultural pesticide use trends and policy issues. agricultural economics report 622, USA Department of Agricultural Economics, Research Services, Washington, D.C.

Pimentel, D., A. Acquay, M. Biltonen, P. Rice, J. Nelson, V. Lipner, V. Giordano, A. Horowitz and M. D'Amore (1992): Environmental and economic cost of pesticide use. An assessment based on currently available data, although incomplete, totals US$ 8 Billion in annual costs. Bioscience Vol. 42, No. 10, pp. 750-760.

Potachnik, G. and Yanai-Inbar (1987): Dibromochloropropane (DBCP): an 8 Year reevaluation of testicular function and reproductive performance. Fertil. Steril., Vol. 47, pp. 317-323.

Robinson, W.E., R. Nowogrodzki and R. A. Morse (1989): The value of honey bees as pollinators of U.S.A Crops. American Bee Journal Vol. 29, pp. 477-487.

Sithole, S.Z. and G .P. Chikwenhere (1994): Integrated pest management in Zimbabwe: IPM implementation workshop for East, Central and Southern Africa. In: Summary Proceedings of a Workshop held in Harare, Zimbabwe 1993. Chatham, U.K. NRI (Natural Resources Institute). pp.83-87

Schonfield, A., L. Wamukonya and S. Glendening (1994): Under African skies: Methyl bromide use and alternatives in Africa. Pesticide Action Network, October 1994. San Francisco.

Thomas, P. T. and R.V. House (1989): Pesticide induced modulation of immune system. pp. 94-106. In: N.N. Ragsdale and R. E. Menzer (eds.): Carcinogenicity and pesticides: principles, issues and relationships. American Chemical Society, Washington, D.C.

Zilberman, A., A. Schmitz, G. Casterline, E. Lichtenberg and J.B. Siebert (1991): The economics of pesticide use and regulations. Science, Vol. 253, pp. 518-522.

World Health Organization /United Nations Environmental Programme (WHO/UNEP) (1989): Public health impact of pesticides used in agriculture. WHO/UNEP, Geneva, Switzerland.

3 The Regulation of Agricultural Pesticides

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Abstract

The number of registered pesticide formulations in Zimbabwe have increased from 552 in 1990/91 to 661 in 1994/95 an average annual increase of 4.25%. This trend is likely to continue in the foreseeable future; until alternate strategies for pest management are developed and utilized. Use of agricultural pesticides indicates farmers' awareness of benefits derived from pesticides and aggressive advertising by the manufacturers in both farming sectors. The benefits of pesticide use include: higher yields, better quality crops free from pests and pathogens for domestic and export market, and saving in labor costs especially in weed control.

The present legislation and regulations governing the pesticide registration in the country has been in use since 1953. Present legislation only deals with manufacture, distribution, and sales, but is silent on pesticide use at farm level. Finally, the present pesticide registration does not require environmental impact studies nor the environmental impact statement under Zimbabwe conditions. Therefore, there is need to review Zimbabwe's pesticide registrations, regulations and procedure. In addition, monitoring of pesticide manufacture, distribution, sales and use, suffers from lack of trained manpower and logistics.

3.1 Introduction

Today, the African economy is the poorest in the world. In a period of 30 years between 1960-1990, Africa moved from a position of food self sufficiency to a hungry, malnourished, improvised and disillusioned continent (RUKUNI, 1994). On the other hand, Zimbabwe is generally considered as an "agricultural success story". In normal rainfall years, it has fed itself and has produced surplus for export. Zimbabwe's self sufficiency and surplus for export could be partially attributed to articulated agricultural system consisting of around 4,500 commercial farmers and approximately 1 million communal farmers. The

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commercial sector is highly developed, employing state of the art technology; whereas the communal and resettlement sector is devoid of the choice of available technologies and resources (fertile land, irrigation, fertilizers, pesticides and storage, etc.).

However, with the population increasing at a rate of over three per cent per annum, environmental degradation and high cost of agricultural inputs are eroding Zimbabwe's capacity to feed itself, leave alone the export. On the other hand, increase in pesticide use and the diversification of commercial agriculture into cash crops such as tobacco and horticultural has increased their net income.

A perusal of the annual reports of Plant Protection Research Institute over the years, reveal that most of the experiments involving pesticides are done for the establishment of pesticide efficacy and not for estimation of crop losses. A similar situation exists in the case of pesticide efficacy trials conducted by the agro-chemical industry in Zimbabwe. Practically all these trials are to show efficacy of a pesticide formulation as a requirement for pesticide registration.

The apathy towards conducting crop loss assessments may have been due to several reasons. Firstly, crops are ravaged by more than one disease or insect, hence the need to apply more than one pesticide at frequent intervals in order to identify the cause of crop loss. This procedure creates an artificial condition that masks the crops loss under field conditions. Secondly, in some cases, control measures for a particular disease or insect may not be available, especially when the insect or pathogen is soil borne, or the pathogen is systemic like wilts, smuts and viruses. Crop losses due to insects and pathogens are location specific as they are influenced by chemical and physical properties of soil and environmental conditions such as temperature, moisture and relative humidity. Finally, there is probably the lack of interest and training in crop loss assessment methodologies on the part of researchers and technicians.

In spite of the inherent difficulties, more and more emphasis is currently being placed on conducting crop loss assessments. These studies could lead to the establishment of threshold values of losses caused by insects and diseases and the development of effective pest management packages including cultural practices, use of host resistance in the development of integrated pest management (IPM) practices and biotechnology. Ultimately, crop loss information would lead to reduction, judicious use of pesticide and development of environmentally sustainable pesticides formulations. In this respect, the agro-chemical industry is playing an important role. Many agro-chemical companies around the globe are spending millions of dollars in research and development to meet the future challenges of producing environmentally safe and effective pesticides. However, not much work is being done on this aspect of pesticide development in Zimbabwe by neither agro-chemical industry nor by public sector institutions.

3.2 Advantages of pesticide use

Historically, disasters in agriculture due to pests and pathogens like in recent times outbreak of Coffee berry disease (*Colletotrichum kahawii*) and frequent outbreaks of migratory pests like locusts and armyworm in sub-Saharan Africa have encouraged the extensive use of pesticide, sometimes without any attempt on environmental impact assessment. In addition, to protect the crops from the catastrophes from pests and pathogens, pesticides have contributed significantly in various ways.

- **Improved yields**

Perhaps the main objective of any pesticide application is to save the crop from the destruction by pests and pathogens and thus obtain better returns from farming. However, the amount of pesticide used is not directly proportional to increased yield. For example, the ratio between pesticide use per unit area of land in Japan and Africa is 85; whereas, the ratio between the corresponding increase in crop yield is only 4.5 (WHO, 1990a). Thus, when the agricultural practices are good (healthy seeds, cultivation practices, irrigation and fertilizers) increased pesticide use provide the opportunity to attain optimum yields.

- **Improved quality and quarantine**

The use of pesticides contributed significantly towards the production of quality crops required by modern day society. However, it is difficult to put monetary value on improved quality versus poor quality. In Zimbabwe, concern for quality of agricultural produce mainly applies to products destined for the export market, to lesser extent for domestic market and household use.

On the other hand, freedom from insects and pathogens of agricultural produce has a very important role in plant quarantine. Under the International Plant Protection Convention (IPPC), the spread of pests and pathogens is jealously monitored, so that exotic pests and pathogens do not get introduced in uninfested areas. Currently this aspect is achieved through the use of pesticides, to lesser extent through cultural practices and produce inspection.

- **Fast knock down efficiency**

The time required for pest control and management with the use of pesticides is relatively small as compared to cultural and sanitation methods and practices. In some cases, pesticides are the only option such as in case of insect infestation in grain, migratory pests, Quelea birds etc. For example, control of aquatic weeds by chemicals shows its effectiveness within a few days of application whereas biological control takes months or years (CHIKWENHERE, 1994). The farmer is able to observe the effect of pesticides almost instantaneously.

- **Saving on labor**

In countries, where there is shortage of labor especially during weeding and harvesting, pesticides have played a pivotal role in increasing farm productivity. Apart from shortage of labor the cost of labor is becoming equally prohibitive in some countries including Zimbabwe.

- **Food security and food self sufficiency**

In the continent of Africa, food security and food self sufficiency are issues of utmost importance. In this respect, pesticides, especially in the commercial farming sector have played an significant role. In Zimbabwe, in the production of almost all commercial crops including maize, wheat, cotton, sugarcane, tobacco and horticultural crops, use of herbicides, insecticides and fungicides for the control of weeds, pests and pathogens is a common practice. In comparison, food deficit in the communal or small scale sector could partly be attributed to lack or limited use of pesticides.

3.3 Limitations to pesticide use

Although, pesticides have significantly contributed towards increased food production and caloric supply over the past three decades (ALEXANDRATOS, 1988; UPTON, 1993; World Bank, 1992), their impact on the small scale farming sector has been negligible and in some cases negative. This anomaly could be ascribed to several factors, such as:

- **Cost of pesticides and equipment**

Most of the pesticides and their application equipment (sprayers, dusters, masks, protective clothing etc.) are expensive and are not affordable by small scale farmers. Even in countries like Zimbabwe, where per capita income is US$ 570 (World Bank, 1994), a subsistence farmer is usually unable to purchase pesticides and equipment until subsidized by the government. On the other hand, subsidies and grants towards pesticides and equipment purchase by governments, donor agencies and international organizations have contributed towards increased and/or indiscriminate use of pesticides.

- **Training**

The use of pesticides requires specialized training in pesticide mixing, application techniques and maintenance of pesticide application equipment. This training is poorly available to small scale farmers either due to low education or lack of training facilities and resources. The situation in most cases has resulted in minimum use of pesticide or their, misuse and in some cases has proved hazardous to human and animal health with concurrent contamination of the environment.

- **Unavailability and poor distribution of pesticides**

Effective and efficient use of pesticides depends on their ready availability within the country and accessibility to the small scale farming sector. In most of the African countries including Zimbabwe accessibility to pesticides has been a perennial problem. This is mainly due to the poor marketing infrastructure as well as the benefit/cost aspect on the part of the agro-chemical industry and their distributors.

- **Storage and disposal of pesticides and pesticide containers**

Users, distributors and manufacturers store agrochemicals including pesticides for varying periods of time. Most of the pesticides have finite shelf lives and tend to loose their activity because of their hygroscopic nature, temperature, light sensitivity and sometimes chemical reactivity. Due to the corrosive nature of pesticides, sometimes the containers leak on prolonged storage.

Some pesticides emit vapors contaminating the atmosphere, thus posing health hazard to workers, farmers and to animals. In some cases pesticides due to poor or careless storage have found their way into food, causing human and animal poisoning, into drainage and eventually into the lakes, rivers and underground waters. Similarly, disposal of empty pesticides containers have posed serious human and animal health hazard as well as contributed towards environmental pollution. (KESWANI, 1995) WHO in collaboration with UNEP has made a comprehensive study on this subject (WHO, 1990b) and have suggested proper procedures on storage and disposal of pesticides and their containers.

- **Pesticide poisoning**

Pesticide poisoning is an inherent and perpetual problem in all countries, wherever pesticides are used. It involves people, domestic animals, birds and aquatic life. Human poisoning and illness caused by pesticides are clearly the highest price paid for pesticide use (PIMENTEL et al. 1992). Although, developed countries use approximately 80% of all the pesticides produced in the world, less than half of the pesticides induced deaths occur in these countries (PIMENTEL, 1990). A higher proportion of pesticides poisoning and deaths occur in developing countries, where there are inadequate occupational and other safety standards, insufficient enforcement, poor labeling, illiteracy, inadequate protective clothing and washing facilities, and insufficient knowledge of pesticide hazards by users.

Recently CHITEMERE (1996) reviewed the deaths caused by pesticide poisoning for the period 1986 to 1990 and showed a declining trend from 119 cases in 1986 to 73 in 1990. This decline of 38.6% over the period of five years may be due to increased awareness on the hazards of pesticide use or due to underreporting.

- **Effect of pesticide use on environment**

The global increase in pesticide use has resulted in discussion and concern on the impact on the environment. The "environment" in broadest terms involves atmosphere, soil, water, microorganisms and insects in soil aquatic life (fishes, algae and fungi), wild life (wild birds and mammals) and finally invertebrates in soil and water. It is virtually impossible to study the effect of pesticide use and their residues on diverse group of living and non-living systems. At the same time a long term pesticide use policy in any country including Zimbabwe needs to consider the environmental aspect. Apparently, instead of dealing with each environmental parameter individually, an impossible task in short and medium term scenario, countries such as Denmark, Netherlands, Sweden and the Province of Ontario in Canada have developed action plans to reduce pesticide use by 50%, while maintaining sustainability of agriculture (NBA, 1988; PIMENTEL et al., 1993).

The issue of human, animal health and environmental hazard in relation to pesticide use is of paramount importance in the interest of sustainable agricultural development in Zimbabwe. Therefore, the present and future use of pesticides would require rational regulatory and monitoring mechanisms.

3.4 Regulation of pesticide use in Zimbabwe

In view of public safety, animal health, environment and optimum use of pesticides in agriculture, the manufacture, sale and use of pesticides is regulated by various Acts and Regulations. These are administered on behalf of the Minister of Lands and Agriculture by the Pesticide Registering Officer based in the Plant Protection Research Institute.

- **Pesticide regulations**

There are several Acts and Regulations that govern plant protection in Zimbabwe. These include the following:

- Fertilizers, Farm Feeds and Remedies Act (CAP 111) Pesticides Regulations, 1977.
- Hazardous Substances and Articles Act (CAP 322)
- Locust Control Act (CAP 126)
- Noxious Weeds Act (CAP 127)
- Sericulture Act no. 25
- The Plant Breeders Rights (CAP 115)
- Seed Act no. 40
- Plant Pests and Diseases Act (CAP 128)
- Plant Pests and Diseases Act (Coffee Regulations 1971)
- Plant Pests and Diseases Act (Cotton Regulations 1971)
- Plant Pests and Diseases Act (Pest Control Regulations 1971)
- Plant Pests and Diseases Act (Tobacco Regulations 1978)
- Plant Pests and Diseases Act (Seed Potato Protection Regulations 1972)
- Plant Pests and Diseases Act (Importation Regulations 1976)
- Plant Pests and Diseases Act (Nursery Regulations 1972)
- Plant Pests and Diseases Act (Pests and Alternate Hosts Order 1976)

Legislation pertaining to the sale of pesticides in Zimbabwe (formerly Rhodesia) was first promulgated through Fertilizers, Farm Feeds and Remedies Act (Chapter III) of 1953. Regulations governing the compulsory registration and sale of pesticides appeared under Government Notice 241 of 1971, subsequently amended by Government Notice 10 of 1977; which was further amended by Statuary Instrument No. 320 of 1981.

In addition, the safe and efficient use of pesticides comes under the domain of Hazardous Substances and Articles Act (Chapter 322) through statutory Instruments No. 205, 263, 313 and 318 which deal with the classification of pesticides according to their toxicity to humans and animals and use of protective clothing by applicators. Hazardous Substances and Articles Act and its statutory instruments are implemented by the Ministry of Health and Child

Welfare in cooperation with Pesticide Registering Officer in the Ministry of Lands and Agriculture. In Zimbabwe, the term pesticide includes fungicides, nematicides, insecticides, acaricides, avicides, arboricides, bactericides, molluscicides, rodenticides, plant growth regulators as well as products intended for domestic and public health use.

- **Registration of pesticides**

Before, a pesticide can be used in Zimbabwe, it must be registered with the Pesticide Registering Officer and a Certificate of Registration be accorded to it. The following are the main requirements for the registration of pesticides:

1. The product must be registered for use in the country of origin.
2. The pesticide registering office only accepts efficacy data generated in Zimbabwe for registration purposes. Efficacy data generated outside the country can only be used to support locally generated data. Data generated over three cropping seasons is required before registration proceeds. This ensures consistence in the performance of the product. Trial data should be generated from at least three locations which are agroecologically different.
3. Efficacy data used for registering a pesticide to control a pest on one crop cannot be used to control the same pest on a different crop.
4. For a change in formulation of a registered pesticide, one year's data is required prior to registration for the control of the same pest on the same control.
5. Toxicology package from the country of origin is acceptable for the purposes of registration.
6. Currently it is not compulsory for information on the product's impact on the environment but it will soon be a requirement in future.

The Chief Pesticide Registering Officer may grant temporary registration whenever there is a limited number of registered pesticides for the control of a particular pest. This is only possible at the end of one year's trial work and when product's efficacy data is promising. Research into the efficacy and use of pesticides in pest management is required by law. Research into other aspects of pesticides is not mandatory but the generation of efficacy data under various climatic conditions prevalent in Zimbabwe is one of the requirements for pesticide registration. Therefore, efficacy experiments are conducted across agroecological zones.

- **Submission of application**

The prospective pesticide manufacturer, formulator or importer must submit an application in triplicate for registration of candidate pesticide on prescribed forms. The application for registration of pesticide should include:

a) Two samples of pesticides formulation, for quality control purposes.

b) Three typed copies of proposed container labels with instructions on application rates, mixing instruction, application intervals, and post application harvesting time etc., efficacy against pest and pathogens, antidotes against accidental poisoning, active ingredient concentration, formulation and expiring dates etc.

c) Three years experimental data under Zimbabwean conditions in support of efficacy of the candidate pesticide.

d) Mammalian toxicity data, method of analysis and where applicable residue and phytotoxicity data under Zimbabwean conditions.

- **Evaluation of pesticide registration application**

Once, the file on pesticide registration application is complete in all respects as indicated above, it is sent to a panel of experts depending on the pesticide category. Applications for insecticides is sent to entomologists, fungicides to plant pathologists, nematicides to nematologists, herbicides to the Weed Research Team in Agronomy Institute of the Department of Research and Specialist Services. Application for pesticides specifically meant for tobacco and cotton are sent to Tobacco Research Board or to Cotton Research Institute, respectively. However, the final mandate for pesticide registration rests with the Head of Plant Protection Research Institute, who is responsible for the implementation of relevant Acts and Regulations on behalf of the Minister of Lands and Agriculture.

After the application for the registration of a pesticide has been evaluated by subject matter specialist, a copy of the completed application along with proposed container label is sent to Hazardous Substances and Articles Control Officer (HSACO) in the Ministry of Health and Child Welfare for hazard classification. Registration of pesticide is deemed to be complete, when the pesticide has been classified and a registration number is assigned. Subsequently, a Pesticides Registration Certificate is issued to the applicant by the Pesticide Registering Officer. A pesticide is initially registered for three years and could be renewed at the expire of initial or subsequent registrations.

In case of emergency, a pesticide can be provided with temporary registration for one year pending its approval for full registration based on the compliance of the stated procedure. Emergency registration is allowed when a new pest outbreak occurs in the absence of a registered pesticide. However, such a registration needs to be based on the availability of efficacy data from a country approved by the Chief Pesticide Registering Officer who is also the Head of Plant Protection Research Institute. Registration proceeds only once a written approval is given by the Minister of Agriculture at the recommendation of the Chief Pesticide Registering Officer. Such a registration is only temporary pending approval of locally generated efficacy data (3 seasons' work). Temporary registration can be renewed annually as long as no alternative product has been identified for the control of the new pest.

- **Toxicological classification**

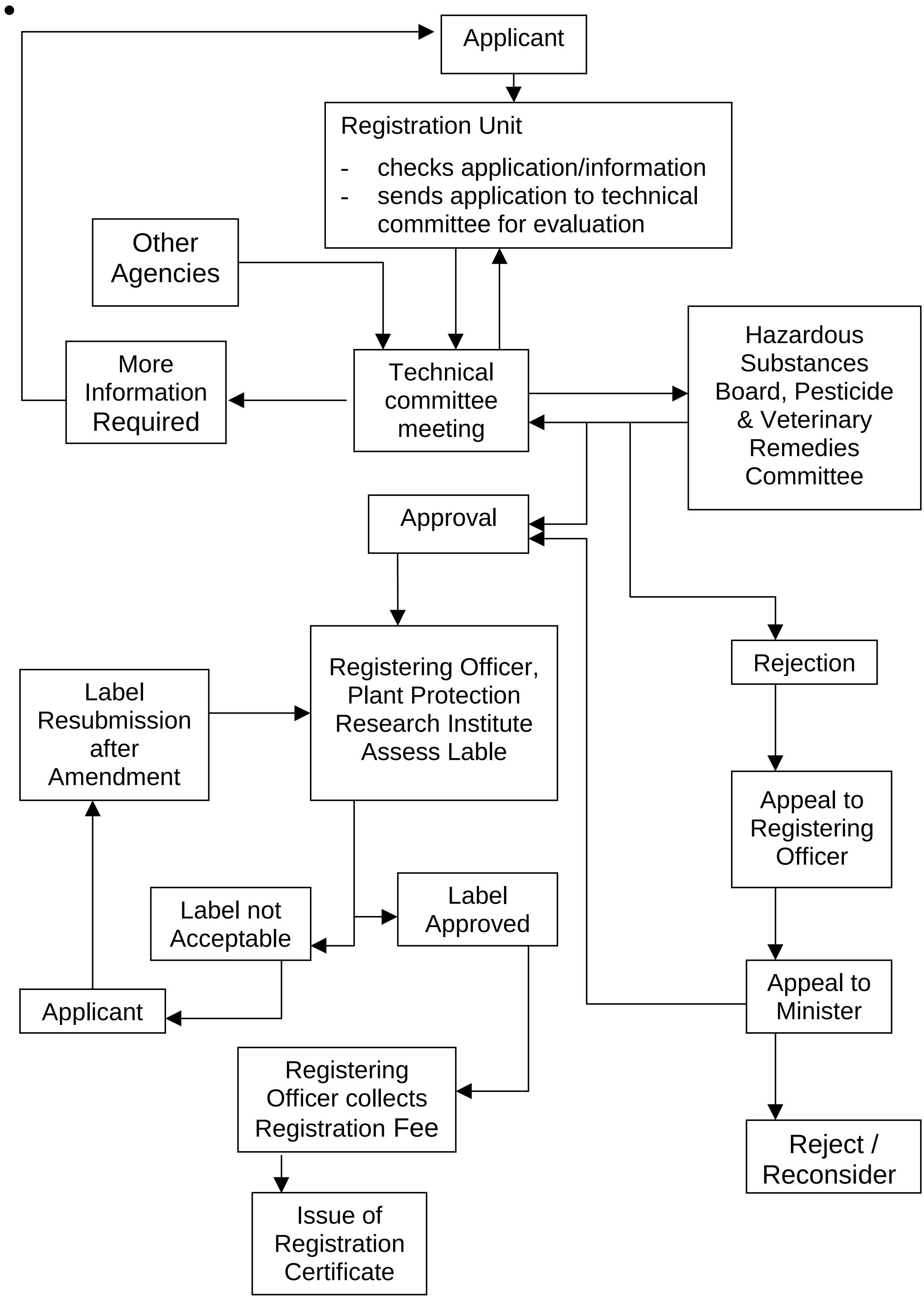
During the registration process, the registering officer, following a decision by the Hazardous Substance and Articles Control Board, assigns a color code (green, amber, red or purple) to a commercially available pesticide. The color code is based on acute oral LD_{50} of the technical material, strength of formulation and persistence of the material after application. The oral LD_{50} is a single dose expressed in mg/kg of body weight which when given by mouth kills 50% of the animals under test. Pesticides bearing the purple triangle (LD_{50} of up to 100) are most toxic while those with a green label (LD_{50} over 2001) are least toxic. Pesticides with the red triangle (LD_{50} of 101-500) are close to the purple group while those with the amber label (LD_{50} of 501-2000) are close to the green category.

- **Experimental pesticide**

Qualified individual, research, educational institutions and registered companies dealing with agro-chemicals are permitted to import reasonable amounts (up to 5l or 5kg) of experimental pesticides. Importers of experimental pesticides must provide the Pesticide Registering Officer with information such as type of pesticide, quantity, propose and experimental site on a prescribed form.

The schematic diagram showing the pesticide registration procedure in Zimbabwe is shown (Figure 3-1). In the case of dispute on pesticide registration, the applicant has a right of appeal to the Minister of Lands and Agriculture.

Figure 3-1: Pesticide registration procedure in Zimbabwe



Labeling and advertising of pesticides

Labeling and advertising of pesticide is considered to be an essential component of the safe use of pesticides in this country. Therefore, every pesticide container carries a label in English, SHONA or NDEBELE (two predominant indigenous languages) providing information on pesticide formulation, use, application method, toxicity classification (in form of colored triangles, green with least mammalian toxicity and purple being the most hazardous, and orange and red being in between), as well as treatment in case of accident. Advertisement of pesticides through press and electronic media on their efficacy and safety need prior clearance from the Pesticide Registering Authority.

- **Packaging and transport of pesticides**

In Zimbabwe, pesticides are packed in different types of containers including 200 liters drums, cardboard boxes, bottles, aerosols and plastic or polythene containers. It is ensured that they are leak proof and comply with the pesticide regulations to avoid or minimize health and environmental hazards. Transportation of pesticides to sale outlets and to ultimate users are through well marked cardboard or wooden containers. Manufacturers and distributors of pesticide advise the transporters on the hazardous nature of pesticides so that they can observe caution and handle the consignments accordingly.

3.5 Present status of pesticide registration in Zimbabwe

At present 661 pesticides are registered in Zimbabwe (see Figure 3-2). Annex 3-1 shows the trend of registered pesticides for the year 1990-1995. Among all the registered pesticides insecticides are most prominent, followed by herbicides and fungicides. Higher number of registered insecticides may have been due to desire and requirement for insect free horticultural produce for export and domestic market to minimize the infestation by quarantine pests. Lower use of herbicides may be attributed to availability of seasonal labor at reasonable wages.

Figure 3-2: Number of registered pesticides

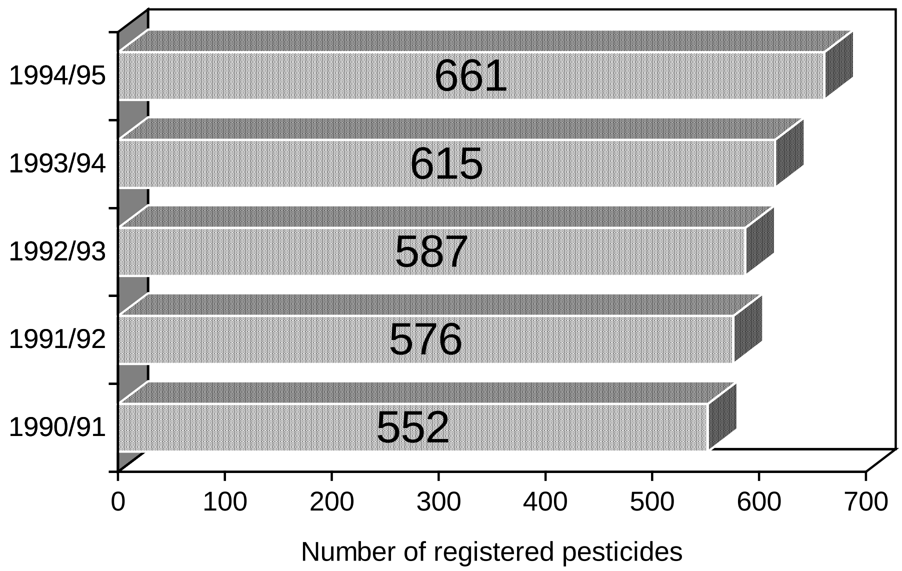
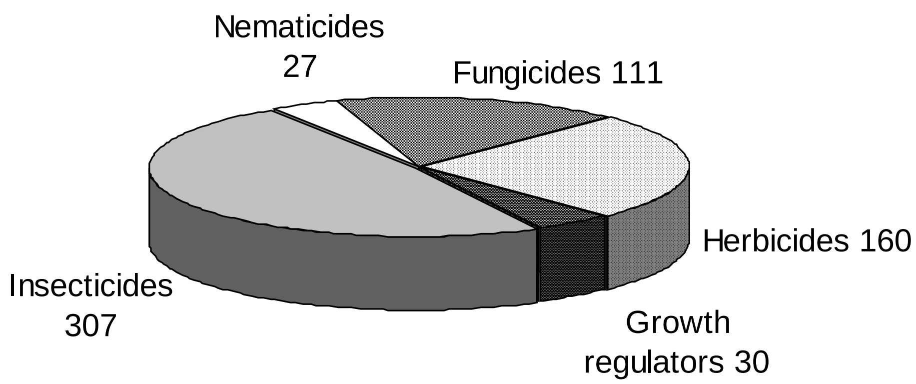


Figure 3-3 shows the number of pesticides registered in the country that fall within the insecticide, herbicide, fungicide, nematicide and growth regulator categories.

Figure 3-3: Registration by pesticide class



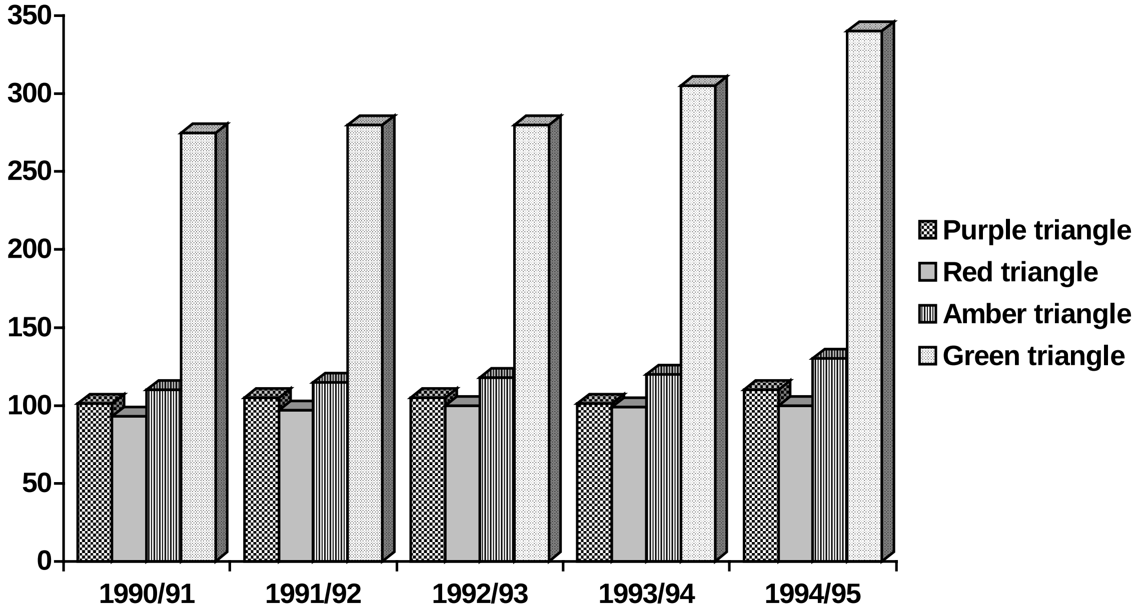
A synoptic description of pesticides used in Zimbabwe includes:

1. **Insecticides** which are compounds or natural products synthesized and formulated for use against insect pests of man, animals and plants.
2. **Fungicides** belonging to a class of pesticides used in controlling fungal diseases. These may be fungicidal when they kill fungi or fungistatic when inhibiting fungal growth on plants, animals or in the soil.

3. **Nematicides** are pesticides used to control microscopic animals called nematodes. Nematodes may be parasitic or gall-forming as often seen in plant nurseries and greenhouses. Nematicides are very expensive, toxic and difficult to apply and their use seems to be limited to the large-scale farming sector growing high value crops such as tobacco, flowers and vegetables.
4. **Herbicides**, sometimes called weed-killers, control weeds or plants growing among economically valued crops. Weeds compete with valued crops for space, water and nutrients in the soil and light. All these conditions are essential for crop production. Thus weeds cause losses in crop yield and quality. Some weeds are parasitic on the host-plant for example *Striga spp.*
5. **Avicides** are used in controlling such problem birds as quelea birds (*Quelea quelea*) which damage cereals and sunflower in the field among other crops.
6. **Acaricides** are pesticides controlling mite pests of crops and livestock.
7. **Rodenticides** are used in controlling problem rodents in the home and field. In the field they cause considerable crop losses and may transmit diseases to man in outbreak years.
8. **Molluscicides** are pesticides which are biologically active against such molluscics as snails which are often secondary hosts of parasites causing disease in man and livestock.
9. **Bactericides** are essentially antibiotics employed to control bacterial diseases of plants and animals including man.

Figure 3-4 depicts the number of registered pesticide according to the level of toxicity during 1990-95.

Figure 3-4: Type of pesticides registered



In Zimbabwe, registration of pesticide increased from 1.5 to 6.9% during 1991-1995 or at an average annual rate of 4.25%. This substantial increase in the same period may be due to increased awareness on the benefits of pesticides use, especially in the large scale commercial and small scale commercial farming sector. On per capita basis Africa is the lowest user of pesticides, even when about 70% of the continents population is agricultural based. On the safety side, over fifty percent of pesticide registered in Zimbabwe carry green-triangle and between 15 and 17% have purple color (see Figure 3-4). The purple labeled pesticides, the most toxic are only sold to commercial farming sector for use as stipulated by law.

The purpose of the legislation is to regulate and restrict the importation and sale of under-grade pesticides, thus protecting the farmer from commercial exploitation. The implementation of the regulations have prevented Zimbabwe from becoming a dumping ground for unwanted agro-chemicals and keeping highly poisonous pesticides from the small-scale farming sector. Farmers and extension personnel are trained by officers from the Plant Protection Research Institute in collaboration with agro-chemical companies on the use of pesticides and safety precautions including the use of protective clothing and disposal of obsolete pesticides and used empty containers.

Legislation ensures that only pesticides whose efficacy and toxicity have been thoroughly investigated, found effective and safe are put on the market for sale. Registration of pesticides is deemed complete when a certificate of registration and a registration number have been issued upon approval of the label submitted by the applicant.

Migrant pest control

The Government of Zimbabwe does not subsidize the procurement of pesticides by all categories of farmers. However, the Government allocates a small budget for use in controlling outbreaks of pests of major importance to the national economy and food security. The budget is used in the management of the African armyworm and locusts which if uncontrolled have serious implications on the national economy and food security. The annual budget is about ZW$ 450,000 and the balance of money remaining at the end of the financial year goes back to treasury.

Migrant pests are irregular in their occurrence. The money is for research into pest management, monitoring and forecasting for early warning purposes and purchasing of resources needed for use during control operations including pesticides, equipment used in pesticide application, and travel and subsistence allowances for personnel involved in research and control operations.

During monitoring and control operations, researchers, extortionists and farmers team up to ensure success in pest control and avert serious crop losses due to migrant pests. In years when migrant pest outbreaks are very heavy the standby budget may be used up and a written justification is prepared for submission to the Ministry of Agriculture requesting for more funds to be made available for control operations.

Pesticides used in migrant pest control are kept in government stores controlled by the PPRI. These chemicals are released for distribution to pest outbreak areas where farmers use them under the supervision of extension officers and personnel from the PPRI. At the end of control operations, unused pesticides are returned for safe keeping in secured stores approved by the PPRI in provinces. In some years, pesticides are provided by donors. The policy is that donors providing migrant pest pesticides should supply only those registered in the country and approved by the PPRI; the designated institution for pesticide registration.

At present the African armyworm is being monitored by pheromone traps which catch moths. The number of moths caught is used in forecasting outbreaks. Zimbabwe has a network of pheromone traps installed at different strategic areas throughout the country. The size of moth catches determines the mobilization of resources for control operations to affected areas.

For the control of armyworm and locust, carbaryl 85% WP is recommended for use in small-scale farming sector and the protective clothing is also provided by Government while commercial farmers are provided with pesticides only for the control of locusts and technical advice for the control of armyworm.

3.6 Monitoring of pesticide manufacturing, formulation, use and misuse

This subject, although of importance, is probably the weakest in Zimbabwe. Under the Fertilizers, Farm Feeds and Remedies Act Chapter 111, government is empowered to monitor the manufacture, formulations, import, use and misuse of pesticides at plant, storage, sales and farm level. However, due to the shortage of trained manpower, this activity is at a minimum level. Presently this activity is based on the goodwill of the industry, distributors, traders and farmers. This area need strengthening, because all the parties involved have stake in safe use of pesticide in agriculture and for the environment as a whole.

Although it is required under the Hazardous Substances and Article Act that every person applying pesticide should put on protective clothing during handling and application a large proportion of small-scale farmers apply pesticides without putting on some of the appropriate protective clothing because of their poor socio-economic status.

The safe use of pesticides includes: use of recommended pesticide concentration, frequency of application, monitoring of pesticide residues and training of pesticide applicators. The government undertakes training pesticide applicators, when the activity is for "public good" such as pesticide use in migratory pest control (locust, armyworm and quelea birds) and in communal areas. The training is offered to government workers and officials in Agricultural and Technical Extension Services (AGRITEX) and in the Department of Research and Specialist Services and is usually supported through donor assistance. Individual manufacturers have undertaken the training responsibility at farm level especially on commercial farms.

Green pesticides (formulations with an acute oral LD_{50} of over 2001) are recommended for use by small-scale farmers. These pesticides can be offered for sale by any shop or store. Pesticides in the more toxic categories may be used in the small-scale farming sector under the strict supervision of knowledgeable extension personnel. This policy, therefore, applies to on-farm testing of candidate pesticides in that the more toxic agro-chemicals are not/rarely tested for their efficacy in the small-scale farming sector. The policy on organochlorine pesticides resulted in the gradual phasing out of some chlorinated hydrocarbon insecticides. For example DDT, dieldrin and aldrin which were used extensively in the control of soil pests like termites have already been banned for use in agriculture.

- **Disposal of empty pesticide containers and obsolete pesticides**

Empty containers of pesticides are of major concern in environmental, human and animal health safety. There are specialized methods such as recycling, incineration and burial of these containers in soil or land fills. In Zimbabwe, agro-chemical industry has a cooperative system among different manufacturers to dispose off large containers. Individual companies follow international standards and procedures for this purpose.

On the farm level, pesticide containers are buried in the soil or burnt in the open fire. During this procedure, workers wear protective clothing, gas masks and follow usual safety precautions. However, accidents do occur, and some reports on this aspect were presented by NHACHI and KASILO (1996).

- **Activities of the agro-chemical industry**

The Global Crop Protection Federation (GCPF, formerly GIFAP) along with the Agricultural Chemicals Industry Association (ACIA) have been active in promoting the safe use of pesticides in Zimbabwe. The latter organization is counterpart of GCPF, which has a global mandate. Both organizations are striving to convey the safety aspect in the use of pesticide through newsletters, posters, training of pesticide manufacturers, farmers and retailers.

- **International Code of Conduct on the distribution and use of pesticides**

Zimbabwe as a country and members of ACIA, prescribe to FAO's code of conduct on the distribution and use of pesticides and adheres to the principles of Prior Informed Consent (PIC). One of the requirements of pesticide registration is, that the concerned pesticide should be registered and be in use in the country of origin or of the manufacture. In this respect the U.S. Environmental Protection Agency (EPA), Agri-Canada and other national regulatory bodies around the world have been of an immense source of information exchange. At the same time, Zimbabwe's classification of pesticides according to hazardous nature is based on the International Programme on Chemical Safety (WHO, 1990b) with the exception that Zimbabwe has devised the protocol of using color triangles on its pesticides containers instead of numerical classes of Ia, Ib, II and III, respectively.

Zimbabwe promotes the Prior Informed Consent (PIC) procedure as a component of the FAO Code of Conduct providing a broad policy framework for pesticide management (Table 3-1). Plant Protection Research Institute is the Designated National Authority and Table 3-1 depicts some actions it has taken in relation to PIC procedure and in response to request by FAO/UNEP Joint Programme on pesticide import decisions.

Table 3-1: Import decisions on some pesticides in Zimbabwe

Pesticide	Final decision	Interim decision	Conditions for import	Remarks
Aldrin	Prohibited			
Dieldrin	Prohibited			
DDT	Prohibited			
Dinoseb & Dinoseb salts	Prohibited			
HCH	Prohibited			All isomers prohibited except gamma isomer
Chlordane	Permitted			Restricted use
Fluroacitamide	Prohibited			
Cyhextin		Prohibited		Still under investigation
EDB	Permitted			No restriction

3.7. Discussion

Crop protection is an constituent element for higher crop yields, quality produce and prevention of quarantine pests from spreading through domestic and international agricultural trade. In these respects, pesticides continue to play an important role, especially in developing countries, where field and post harvest losses remain high. In the decades of the 60s' and 70s', the use of pesticide was mainly governed by economic considerations of farming and very little attention was paid to human and animal health and to the environment.

In the case of Zimbabwe, if the number of registered pesticides is an indicator of pesticide use in agriculture, then it clearly shows an increasing trend at an average annual rate of 4.25% over the past five years (1991-1995). The commercial farming sector remains the major user of pesticides in Zimbabwe due to the economic capacity, higher net return on cash crops, and the technical know how on effective use of pesticides and equipment.

With growing economic and technical empowerment of the small scale farming sector, there is a likelihood of increased pesticide use in the named sector in future. The increased use of pesticides in overall agricultural scenario of Zimbabwe is also contributed by agro-chemical industry's aggressive advertisement campaigns on the virtues of pesticides. The main issue therefore is: does the progressive increase in pesticide use will stop or even go down? The answer to this question probably lies with alternate options to pesticides use including development of IPM technologies and packages, and development of host plant resistant against pests and pathogens, availability of cultural practices such as crop rotations and sanitation etc. In this respect biotechnology will also play an important role in the future. But recent reports on genetically engineered resistance in plants against pests and pathogens points forwards cautious approach.

Legislation governing the pesticide registration and its operational procedures are very well entrenched in the system, but require review and revision. Pesticide registration in Zimbabwe suffers from shortage of manpower; consequently very little attention is paid to evaluation of field trials intended for efficacy data generation, toxicological as well as residue analyses. The residue analysis capability is further aggravated due to outmoded equipment and operational resources in the Department of Research and Specialist Services; an agency responsible for this service. Even the monitoring of manufacturing facilities and its occupational health hazards, distribution, sales and application of pesticides in the field is an inherent weakness, also attributed to shortage of manpower, transport and operational resources.

Training of field applicators of pesticides is a matter of concern, although a responsibility of AGRITEX and Department of Research and Specialist Services. Assistance of agro-chemical industry and international donors would alleviate this constraint in the short and medium term.

The present pesticide regulations are silent on import of pesticides by individual farmers. Further, the legislation only deals with manufacture, distribution and sale and not the use. Finally, Zimbabwe pesticide registration has no requirement on environmental impact assessment and/or environmental impact statement. These issues could be considered as deficiencies in registration procedure, hence require assessment of the pesticide regulations and possible amendments.

Agro-chemical industry and research institutions in Zimbabwe, since their inceptions have basically engaged in field trials to generate efficacy data. In other words, their activity is towards market development, rather than research and development. Of course some industrial houses have made attempts on research and development; for example, development of *Trichoderma sp.* for soreshin disease control in tobacco, and improved pesticide formulations based on indigenous materials.

The recent publication "Pesticides in Zimbabwe; toxicity and health implications“ has successfully elaborated the issue of institutionalisation and policy need on monitoring and reporting of pesticide poisoning and environmental pollution (NHACHI and KASILO, 1996). Therefore, the pesticide registration policy would require harmonisation based on combination of biological factors (host/parasite interactions, efficacy of pesticides), benefit/cost, and environmental consideration and animal and human health risk assessments.

References

Alexandratos, N. (ed, 1988): World agriculture towards 2000. London: Belhaven Press.

Chitemere, R.C. (1996): Pesticides and occupational safety and health in Zimbabwe. In: C.F.B. Nhachi and O.M.J. Kasilo (eds.), Pesticides in Zimbabwe: Toxicity and health implications. University of Zimbabwe Publications. P.O.Box MP 167, Mt. Pleasant Harare, Zimbabwe, p. 16-24.

Chikwenhere, G.P. (1994): Biological control of water lettuce in various impoundments of Zimbabwe. Journal of Aquatic Plant Management, Vol: 32, pp. 27 - 29.

Colvin, B.M. (1987): Pesticide uses and animal toxicoses. Veterinary and Human Toxicology, Vol. 29 (Suppl 2), 15 pp.

Keswani, C.L. (1995): Environment friendly techniques of agrochemical use. Paper presented at Workshop on Marketing of Agri-Inputs in the liberalised environment in Zimbabwe. Harare, May 2 - 5, 1995. African Centre for Fertiliser Development, P.O. Box A 469, Avondale, Harare, Zimbabwe, pp. 12.

Natural Board of Agriculture (NBA) (1988): Action programme to reduce risks to health and the environment in the use of pesticide in the agriculture. General Crop Production Division, National Board of Agriculture, Stockholm, Sweden.

Nhachi, C.F.B. and O.M.J. Kasilo (eds. 1996): Pesticides in Zimbabwe: Toxicity and health implications. University of Zimbabwe Publications. P.O.Box MP 167, Mt. Pleasant Harare, Zimbabwe.

Pimentel, D. (1990): Estimated annual world pesticide use In: Facts and Figures. Ford Foundation, New York.

Pimentel, D., H. Acquay, M. Biltonen, P. Rice, M. Silve, J. Nelson, V. Lipner, S. Glordano, A. Horowitz and M. D'Amore (1992): Environmental and econominc costs of pesticides use. BioScience, Vol. 42, pp. 750 - 760.

Pimentel, D, H. Acquay, M. Biltonen, P. Rice, M Sliva, J. Nelson, V. Lipner, S Glordans, A Horowitz and M. D'Amore (1993): In: D. Pimentel and H. Lehman (eds): The Pesticide question - environment, economics and ethics, Chapman & Hall, New York, London, pp. 47 - 84.

Pimentel, D. (1993): Reducing pesticide use through alternative agricultural practices: Fungicides and herbicides. In: J. Altman (ed.): Pesticide Interactions in Crop production: Beneficial and Deleterious Effects. Boca Raton (USA): CRC, pp. 435 - 448

PSAC (1995): Restoring the quality of our environment, Report of the Environmental Pollution Panel, Presidents Science Advisory Committee. The White House, Washington D.C., USA., November, 1995.

Rosenberger, D.A. (1985): Reducing fungicide use in agriculture: benefits, risks and unexpected outcomes. Phytopathology, Vol. 85, pp. 1560.

Rukuni, M. (1994): The prime movers of Zimbabwe's agricultural revolution. University of Zimbabwe Publications Office, P.O. Box MP 167, Harare, Zimbabwe, pp. 1 - 10.

Upton, M (1993): The economics of food production. In: Crop Protection and Sustainable Agriculture. Ciba Foundation Symposium 177. Chichester (U.K): John Wiley & Sons. pp. 61 - 75.

World Bank (1992): World Development Report : Development and Environment. Oxford (UK): Oxford University Press.

World Bank (1994) World Development Report: Infrastructure and Development. Oxford (UK): Oxford University Press.

WHO (1990a): Public health impact of pesticide used in agriculture. WHO, Geneva (Switzerland), pp 21.

WHO (1990b): International Programme on Chemical Safety (IPCS). The WHO recommended Classification of Pesticide by hazard and pesticides guidelines to classification 1990 - 1991. WHO/PCS/90.1. pp. 37.

Annex 3-1: Number of different categories registered pesticide formulations in Zimbabwe (1990/95)

Year	Type of pesticide category	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Total by category
90/91	Purple	-	-	2	71	19	-	2	-	-	-	-	-	-	-	94
	Red	-	11	14	48	-	1	4	1	-	-	2	-	3	-	84
	Amber	-	20	27	48	-	4	1	-	-	1	-	-	-	1	102
	Green	-	65	81	97	-	5	18	-	-	5	-	1	-	-	272
	Total	**-**	**96**	**124**	**264**	**19**	**10**	**25**	**1**	**-**	**6**	**2**	**1**	**3**	**1**	**552**
91/92	Purple	-	1	4	71	22	-	1	-	-	-	-	-	-	-	99
	Red	-	12	15	51	-	1	4	1	-	-	2	-	3	-	89
	Amber	-	20	28	49	-	5	1	-	-	1	-	-	-	1	105
	Green	-	67	88	98	-	4	19	-	-	6	-	1	-	-	283
	Total	**-**	**100**	**135**	**269**	**22**	**10**	**25**	**1**	**-**	**7**	**2**	**1**	**3**	**1**	**576**
92/93	Purple	-	1	4	71	22	-	2	-	-	-	-	-	-	-	100
	Red	-	12	16	55	-	1	4	1	-	-	-2	-	3	-	94
	Amber	-	20	30	30	-	4	1	-	-	1	-	-	-	1	108
	Green	-	69	88	100	-	5	17	-	-	5	-	1	-	-	285
	Total	**-**	**102**	**138**	**277**	**22**	**10**	**24**	**1**	**-**	**6**	**2**	**1**	**3**	**1**	**587**
93/94	Purple	-	1	4	66	25	-	1	-	-	-	-	-	-	-	97
	Red	-	12	16	56	-	1	4	1	-	-	2	-	3	-	95
	Amber	-	22	30	55	1	5	1	-	-	1	1	-	-	1	117
	Green	-	71	98	106	-	5	20	-	-	5	-	1	-	-	306
	Total	-	**106**	**148**	**283**	**26**	**11**	**26**	**1**	**-**	**6**	**3**	**1**	**3**	**1**	**615**
94/95	Purple	-	2	8	73	26	-	1	1	-	-	-	-	-	-	110
	Red	-	12	16	58	-	1	5	1	-	-	2	-	2	-	398
	Amber	-	23	32	57	1	5	1	-	-	1	1	-	1	1	132
	Green	-	74	104	119	-	5	23	-	-	5	-	1	-	-	331
	Total	-	**111**	**160**	**307**	**-27**	**11**	**30**	**1**	**-**	**6**	**3**	**1**	**3**	**1**	**661**

Source: Pesticide Registration Office, Plant Protection Research Institute, Harare.

A- Aboricides; B- Fungicides; C- Herbicides; D-Insecticide; D- Insecticides; E- Nematicides; F- Rodenticides; G- Growth Regulants; H- Defoliant; J- Dessicant; K- Molluscide; L- Avicides; M- Repellent; N- Bactericides; P- Viricides

4 The Development of the Pesticide Industry in Zimbabwe

Joseph Rusike[1] and Godfrey D. Mudimu[1]

Abstract

The paper describes the history of the pesticide industry in Zimbabwe, analyzes the structure of the industry and the conduct and performance of pesticide firms.

Data used in this paper were collected through a survey of companies, government organizations, farmers' organizations, and research laboratories engaged in research and development, information dissemination, formulation and manufacturing, and marketing of pesticides in Zimbabwe.

The pesticide industry in Zimbabwe began to emerge in the 1950s. Initially it grew through market expansion of multinational companies based in South Africa, Europe and the United States. The companies gradually developed production and marketing facilities for fertilizers, pesticides, and veterinary products in Zimbabwe. By 1980 a cartel controlled pesticide trade through Agricultural Input Priority Committees and membership of the Agricultural Chemical Industry Association.

The high rate of growth of demand of pesticides over the past decade because of the rapid expansion of the horticulture, cotton, and tobacco industries combined with high product differentiation has favored high concentration of the industry.

A number of factors create effective entry barriers. Many pesticide industry's players are multi-industry and multi-product firms often operating across international boundaries. As much as 50% of the products handled by pesticide companies are specialty products, there is a high degree of product differentiation that further raises entry barriers.

Pesticide companies sell more than 90% of their products directly to farmers through company-owned depots, salespersons and agents. Most distributing companies use company-employed representatives to promote their products to farmers.

The pesticide industry has become competitive following Economic and Structural Adjustment Program (ESAP) policy reforms that the government has implemented since 1992. The increase in competition is expanding the

[1] Department of Agricultural Economics and Extension, University of Zimbabwe, Harare.

availability and range of pesticide products, thereby increasing farmers' choice of these products.

One recommendation from the study is that companies importing already registered generic products should not be made to go through the three-year testing period. The registration process should be streamlined to allow more players. The industry should come up with a trade monitoring body to regulate individual firm behavior and protect the farmers.

4.1 Introduction

The conceptual framework used to derive hypotheses about the relationships between the organization of the pesticide industry, behavior of pesticide firms and economic performance and how they change over time and guide data collection and analysis is the Industrial Organization (IO) or Structure-Conduct-Performance (SCP) framework of analysis.[2] This posits that in the pesticide industry certain basic conditions determine its structure (SCHERER and ROSS, 1990). In turn, the structure determines the behavior of organizations engaged in pesticide research and development, manufacturing, and marketing. Finally, the behavior of pesticide firms determines the industry's performance. Government policies influence the basic conditions, structure and conduct and performance of the pesticide market. Public policies include farm input policies that affect the pesticide industry only, agricultural policies that affect the pesticide industry through their effects on the agricultural sector as a whole, and macroeconomic policies that affect the pesticide industry through their economy wide effects on the business environment within which pesticide firms operate.

Basic conditions are classified on the basis of supply and demand and are schedule shifters. On the supply side basic conditions include the location and ownership of essential raw materials; nature of the technology; durability of the product; and value to weight ratio of the product. Most important, supply side basic conditions include legislation governing pesticide importation, manufacture, sale, and use; and socioeconomic values of pesticide business persons such as attitudes towards cooperation or individualism. On the demand side, basic conditions include price elasticity of demand; availability and cross-price elasticity of demand for substitute products; rate of growth of demand; cyclical and seasonal variability of demand over time; methods used by buyers in purchasing such as institutional demand through government

[2] The structure-conduct-performance model was developed by the Harvard Business School more than 50 years ago.

programs for eradication of plague pests that are national problems and credit programs; and marketing characteristics of the product sold.

Structure includes characteristics that influence competition in the marketplace such as number and size distribution of pesticide companies; degree of product differentiation among competing sellers' products; barriers to entry of new firms; vertical integration; product line diversification; and conglomerate-ness.

Conduct includes methods employed by pesticide companies in determining prices and output, product line and advertising strategies, market channels activities, research and development commitments, legal tactics such as enforcing patent rights, lobbying, public relations, and conglomerate behavior.

Industry performance refers to how well the industry does the things society might expect it to do, including technical and operational efficiency, pricing efficiency, progressiveness, employment, and equity. Government policies include government programs on basic research and development, provision of physical infrastructure, grades and standards, information, price controls, licensing of traders and products, product liability, intellectual property rights laws, and regulatory policies, and laws relating to collusion, mergers, and discriminatory practices. Also, government policies include macroeconomic policies such as monetary policies (money supply, interest rates, credit), fiscal (public expenditures, taxation, borrowing), incomes (wage and price controls), trade (foreign exchange rates and regulations, tariffs, import and export controls), and foreign investment (capital flow regulations, ownership requirements).

The central hypothesis that flows from applying this SCP framework to the Zimbabwean pesticide industry is that the easier it is for new companies to enter the industry, the more firms in the industry, and the more even their size distribution. This leads to increased competition among pesticide firms, better design, quality, and availability of products, faster introduction of new products, better supply of information that farmers require to use pesticides and marketing services productively, lower costs, profits and prices paid by farmers and better economic performance. By contrast the more difficult it is for new companies to enter, the fewer the firms in the pesticide seed industry and the more uneven are their size distribution. The lower the competition among pesticide firms, the poorer the design, quality, and availability of products, the slower the pace of new product innovation, the lower is the supply of market information supplied to farmers to use pesticides productively, the higher the costs, profits and prices paid by farmers and the poorer is the economic performance.

The objectives of this chapter are to:

(a) Describe the history of the pesticide industry in Zimbabwe focusing on changes in its structure and major trends;

(b) Analyze the structure of the industry and the conduct of pesticide firms;

(c) Assess the resulting economic performance and identify alternative policies for improving the industry's performance.

Data used in this paper were collected through a survey of companies, government organizations, farmers' organizations, and research laboratories engaged in research and development, information dissemination, formulation and manufacturing, and marketing of pesticides in Zimbabwe. Interviews were conducted with officials in the Ministry of Agriculture, and representatives of pesticide companies, farmers' unions, and the Agricultural Chemical Industry Association (ACIA) during January and February 1996. The interviews used a structured open-ended questionnaire designed to gain respondents' knowledge, perceptions, and insights into the organization and functioning of the industry. Secondary data were obtained from company brochures, central statistical offices, Ministry of Agriculture, and the Registrar of Companies.

4.2 History of the Zimbabwean pesticide industry

Zimbabwe's pesticide industry began to emerge in the 1950s and initially grew through market expansion of multinational companies based in South Africa, Europe and the United States. For example, Windmill was established in 1947 when Windmill Holland, a Dutch farmer-owned cooperative formed in Holland in 1928 to contain the costs of fertilizers to farmers, had built the largest superphosphate factory in Europe and was looking for off-season export markets in Southern Africa. The company gradually developed production and marketing facilities for fertilizers, pesticides, and veterinary products in Zimbabwe. Similarly, Milborrow Animal Health (formerly Milborrow and Company) was registered in 1951 as a wholly owned subsidiary of Milborrow and Company in South Africa, which in turn was a subsidiary of Glaxo Group Limited of London, to supply veterinary medicines, instruments, and equipment. Cyanamid (formerly Shell Chemicals) established a subsidiary in Zimbabwe in 1952 to market its products. During the same year, Technical Services (Africa) was founded by a British helminthologist to import and distribute agricultural fumigants and insecticides. These companies were followed by Hoechst which established Chemimpo company in 1956 to import and distribute agricultural, industrial, pharmaceutical and veterinary chemicals and medicines. This company was a subsidiary of Chemimpo South Africa, which in turn was a subsidiary of Dutch and Overseas Trading of Holland. The company changed its name from Chemimpo to Hoechst in 1960 after its largest supplier, Hoechst of Germany, acquired 50% of the equity in Chemimpo.

Pfizer Corporation (United States) established a subsidiary, Central African Pfizer Limited, in 1957 to manufacture and distribute pharmaceutical, agricultural and chemical products. In 1993 Pfizer changed its name to Graniteside Chemicals after Pfizer pulled out of most developing countries. Cooper (Zimbabwe) was registered as Cooper, McDougall and Robertson (Central Africa) in 1957 but later changed its name to Cooper (Rhodesia) in 1972 following a worldwide change by the Cooper group of companies that were in turn part of the Wellcome Foundation group of companies, a wholly British controlled group with extensive trade worldwide. Cooper changed its name to Wellcome (Zimbabwe) in 1990 to project the "Wellcome" image, the group's worldwide policy. To restructure its group activities in line with diverse business activities undertaken within Zimbabwe, Wellcome changed its name to Ecological Marketing of "Friendly" Products (Ecomark) in 1992. Ecomark is now trading as Agrevo after merging of Schering and Hoechst. Bayer (formerly Agro-chem) was established in 1961 as a 100% subsidiary of Bayer Agro-Chem in South Africa which in turn was 50% owned by Bayer Foreign Incorporated of Canada. Bayer Foreign Incorporated of Canada was, in turn, a subsidiary of Farbenfabriken Bayer AG of Germany.

Starting in the mid-1960s, the pattern of growth through market expansion by multinational companies began to change following the imposition of international sanctions on Zimbabwe as result of the Unilateral declaration of Independence by the Ian Smith government. A number of Zimbabwean-based firms were established to deal with sanctions. For example, Agricura was incorporated in 1965 as a subsidiary of Agricura Limited of South Africa with 50% equity and the other 50% equity being controlled by Tobacco Sales Limited (Zimbabwe). Agricura became engaged in the production and distribution of crop chemicals, cosmetics, detergents, maize and stockfeeds. Similarly Spray Equipment was incorporated in 1965 to trade as agents for veterinary, pharmaceutical, fertilizers, insecticides, and livestock foods suppliers and manufacture agricultural sprayers and equipment. The Zimbabwe Fertilizer Company (ZFC) was incorporated in 1971 to manufacture and distribute fertilizers and crop chemicals to the agricultural industry. Similarly, the Zimbabwe Phosphate Industries (formerly Rodia Chemical Industries) was registered in 1972 as subsidiary of African Explosives and Chemical Industries (AECI), part of the Anglo American Corporation of South Africa and Zimbabwe, to manufacture fertilizers, disinfectants, animal dips, pesticides, and herbicides. The Zimbabwe Phosphate Industries also owned Dorowa Minerals, the only supplier of phosphate apatite in the country. The growth of Zimbabwean-based pesticide companies was fostered by the foreign exchange allocation system and import licensing which restricted repatriation of profits made to sales among subsidiaries of multinational firms and made it difficult for potential entrants to enter the pesticide business.

By 1980 a cartel controlled pesticide trade through Agricultural Input Priority Committees and membership of the Agricultural Chemical Industry Association.[3] Only multinationals with access to foreign currency, and human resources to overcome entry barriers could enter the pesticide trade. For example, May and Baker was registered in 1980 as a subsidiary of May and Baker United Kingdom. May and Baker later changed to Rhone-Poulenc Zimbabwe in 1988. The first black-owned agrochemical company, Tenfatt, entered the business in 1989 to manufacture agrochemicals and assemble spraying and irrigation equipment. However, with high interest rates which rose from 14 to 45% in the 14 month period from 1991 to 1993 and then settled to around 33% in 1994 - 1995, Tenfatt was unable to meet its financial commitments requiring it to refocus its core business from pesticide manufacturing to distribution.

The industry is restructuring under the Economic and Structural Adjustment Program carried out since 1991. This has stopped access to foreign exchange by a few privileged firms through the Agricultural Input Priority Committee system, increased competition between existing firms and opened opportunities for new businesses to enter the industry. However, the lack of incentives for manufacturing in the country and high interest rates have led multinationals such as Bayer and Ciba-Geigy to move their marketing operations in South Africa where they obtain export incentives. Similarly, Hoechst has closed its formulation plant in Zimbabwe and is contracting with other companies to formulate its products. Shell Chemicals has been acquired

[3] The Agricultural Input Priority Committees system was established by the then Ministry of Lands, Agriculture and Rural Resettlement in the 1980s to estimate planned crop areas and livestock numbers and calculate the agricultural chemicals and veterinary medicines, fertilizers, agricultural machinery, livestock food ingredients and packing materials needed by farmers. This information was used by the Ministry of Trade and Commerce to assess the foreign exchange requirements of agriculture and help with the rationing of foreign currency among different imports.

by Cyanamid. At the same time new entrants have entered with innovative products. Bunting and Associates which was formed in 1993 is now handling biocontrol agents. Similarly Copperts is selling biocontrol products through the Horticultural Promotion Council.

4.3 Status of the Zimbabwean pesticide industry

Currently, the industry is organized into agents and distributors because of division of labor and specialization among firms to permit the capturing of economies of scale and scope. Thirteen companies that trade as agents and local representatives of multinational chemical companies and compete directly in the marketplace: Windmill, ZFC, Agricura, Cyanamid, Technical Services, Sprayquip, Graniteside Chemicals, Agrevo, Milborrow, Tenefatt, Bunting, and Copperts. Nine subsidiaries of multinationals do not directly compete in the marketplace but supply other companies with products: Novartis formed as a result of the merger between Ciba-Geigy and Sandoz; Agrevo; Bayer; BASF; Cyanamid; Zeneca; Rhone-Poulenc; Sumitomo and Monsanto. Novartis has done a few direct sales to smallholders and commercial farmers but these have been limited by the massive financial, transportation, and human resource investments and time needed to set up distribution channels. Cyanamid distributes for itself in the country.

Because Economic Structural Adjustment (ESAP) policies started since 1991, the pesticide and pharmaceutical industry has been getting more competitive over the past five years particularly for commercial farmers. Marketing service is now the key factor determining a company's success in the industry. However, in smallholder areas only one or two companies are represented in different geographical areas and this results in local monopolies.

4.3.1 Basic Conditions

Six basic conditions critically influence the structure of the pesticide industry in Zimbabwe. First, the research and development (R & D), commercialization, and manufacturing of pesticides are complex and sophisticated processes. For example, to get one commercializable product as much as 10 to 15 thousand substances are screened through several stages covering more than 10 years. Thus, the cost of developing a new pesticide requires massive investments and high technology to screen different promising molecules. Furthermore, the economies of scale and scope in pesticide manufacturing exist at the international level and are such that minimum efficient plant scale is achieved by having a multipurpose plant in only one part of the world and exporting to different country markets. For example, Shell Chemicals has only one plant in Holland that supplies its worldwide markets.

Formulation of pesticides with imported active ingredients is possible in Zimbabwe. Although some herbicides, insecticides, and fungicides are formulated and repacked in the country, most chemicals are imported already formulated. This is because formulation still requires high levels of sophistication and technology. In addition, companies can only formulate generic products and there are no incentives to formulate unless transport costs are less on pre-formulated products compared with finished products. Because of the high value of active ingredients in chemical imports there are only minimal benefits from local formulation. In the past, formulation has been carried out primarily to save foreign exchange.

Second, the durability and high value to weight ratio of pesticides determines market structure because these products can be marketed internationally, thereby expanding the territorial spread of markets to global markets. Pesticides are not bulky and used in relatively small quantities compared with fertilizers. This characteristic also favors the international marketing of pesticides. Because pesticides are complex products, they are distributed through specialized or exclusive distribution channels.

Third, pesticide legislation and regulations and enforcement mechanisms affect the industry's structure by influencing who can trade, who has access to what products, whose rights get counted in the marketing system. Because pesticides are harmful if improperly used, all pesticides are required to be registered before they can be sold to farmers. Pesticide registration procedures affect the structure of the industry because applicants are required to submit experimental data on efficacy and toxicity of the product to the registering officer. Thus, to register a new product, pesticide companies have to carry out efficacy trials in the field for at least three years and the data has to show uniformity in performance of the pesticide for at least two years. In theory government officers are supposed to visit experimental sites and check trials. In practice, pesticide companies have to provide transportation and subsistence allowance to government research officers. Therefore, firm size and resources are critical. Moreover, the system is open to abuse because the government has a lack of staff and resources to go and check trials and private researchers can write the required three years of trial data in one afternoon on a desk without carrying out any trials. In addition, the product has to perform better than a standard pesticide before it can be registered. The three years of trial data requirement apply to all products whether they are toxic as DDT or harmless as pheromones. Three years of experimental data are also required for generic products though test information becomes available in the public sector after the expire of patents. This imposes barriers to entry for new companies because entering the pesticide business when required to fund efficacy trials for three years before making a single sale is difficult. Also the actual registration may take more than three years because pesticide registering officers cannot cope with work as the government is imposing across the board cuts in budgets under the structural adjustment program. Registrations which used to take six months from the time of submission of application forms now take an average of two years. Another barrier to entry imposed by the registration scheme is that when importing finished products. Registrations are related to a source by country and company formulations and even solvent. For example, if a company that holds a registration for importing a certain level of dimethoate in a solvent from the United States after the three-year trial data process wishes to import the same product from China it needs to undertake registration trials for another three years. This imposes restraints on the global sourcing of products by companies holding registrations. Finally, the pesticide registration scheme affects market structure because it can be captured by vested interests and used to prevent new entry. For example, companies are required to obtain registration and go through the three-year trial data process for generic products that are already being marketed by another company. Alternatively the company can import the product under the label of the registration holder and pay commission for an already registered label.

Fourth, the high price elasticity of demand of pesticides and unavailability of substitutes affects market structure because they decrease competition that can force price cuts in existing products or offer performance levels. This favors concentration of the industry.

Fifth, the high rate of growth of demand of pesticides over the past decade because of the rapid expansion of the horticulture, cotton, and tobacco industries combined with high product differentiation favor high concentration of the industry. Advertising tends to increase the industry's concentration.

Finally, the cyclical and seasonal demand variability of pesticides affects market structure because companies make businesses only during certain times of the year and production is bunched in a few seasons. This increases diversification and conglomerateness.

4.3.2 Structure

Because of the high technology required for conducting pesticide R & D and manufacturing, durability and high value to weight ratio of pesticide products, high price elasticity of demand for pesticides, and cyclical and seasonal demand variability of pesticides, the international pesticide industry is highly concentrated. In the early 1970s the top 10 companies had a combined market share of 57% of the world market and this has now increased to around 75%, suggesting a trend towards greater concentration (SZMEDRA 1994). This trend will most likely continue in the future and affect the supply of new products to Zimbabwean farmers. Despite the high concentration of the international pesticide industry, it is highly competitive because multinational research companies need to sell their products in as many markets as possible throughout the world to realize a competitive rate of return on their investment in R & D.

The Zimbabwean pesticide industry is more concentrated than the global pesticide industry because the limited access to foreign currency has in the past acted as a barrier to entry by potential entrants and reduced competition among existing suppliers. In 1992 the top five companies had a combined market share of 99% (SZMEDRA, 1994). Although the industry is getting more competitive there are still several barriers to entry of new firms. First, companies engaged in the pesticide industry require good quality control facilities and laboratories to monitor the products that they handle. Second, companies require R & D staff and financial resources to conduct trials to get registration. There are now commercial firms that conduct contract pesticide R & D for registration for companies that lack their own facilities. Third, companies need to obtain access to raw materials if they do formulation and finished products. Quality control is critical because many products on the world market are useless and dangerous. Because impurities in pesticide products can make them highly dangerous, most multinational pesticide manufacturers will not enter a distributor agreement with companies that lack quality control facilities. Finally, companies require access to distribution networks or sell to other companies with established supply networks. Distribution networks are critical for pesticide sales because considerable investment in depots, human resources, transportation and salespersons and decades of trust are required to build relationships with farmers.

Because as much as 50% of the products handled by pesticide companies in Zimbabwe are specialty products, there is a high degree of product differentiation which further raises entry barriers. Specialty products are marketed through exclusive distributors because of the need to promote them with superior marketing services. Thus, there is a high degree of vertical integration in the industry that increases concentration. Many pesticide industry's players are multi-industry and multi-product firms often operating across international boundaries.

Because ZFC and Windmill were allocated relatively more foreign currency in the pre-ESAP era, they became strong in fertilizers and pesticides. For example, ZFC leads the pesticide industry today with a market share of 30%, followed by Agricura with 30%, Cyanamid (Shell) with 19%, Windmill with 15% and Sprayquip with 12%. However, foreign exchange restraints have been falling and companies specializing in agrochemicals have entered the industry. ZFC and Windmill will unlikely hold onto their market shares over the next five years unless they specialize in agrochemicals.

4.3.3 Conduct

Before the Economic Structural Adjustment Program, the government rationed foreign exchange to members of the Agricultural Chemical Industry Association. The members submitted a list of chemicals that needed to be imported to the ACIA for discussion with government officials at Agricultural Input Priority Committee meetings. The government, farmers' unions, the Zimbabwe Tobacco Association would agree on crop areas that they expected farmers to plant the following year. This was largely determined by fertilizer sales. The pesticide industry would agree on chemicals used on these crops, estimate the volumes required on those crops, determine stocks and calculate the volume that needed to be imported. This process led to a cartelization of the industry, as competing companies could collude and jointly determine output and prices. For example, different companies could import dimethoate through only one company, set monopoly prices, and share sales and profits. In addition, because the amount of products companies could import was short, firms would try to make more money out of those products that they managed to import.

Since the introduction of economic reforms, companies are no longer restricted by foreign exchange and can bring products that they want provided these are registered in the country. However, companies have not brought in more imports than in the past because imports are being restricted by high interest rates. Pesticide company representatives reported that they sometimes bring in fewer chemicals than they expect to sell because their objective is not to carry stocks as they cannot finance them. Also, in the pre-ESAP period companies could finance carry over stocks by charging high margins as there was less competition. However, most companies are using conservative short-term financial management policies and they would err on short supply rather than oversupply of products. Estimating the size of crops farmers are likely to plant is difficult because commercial farmers, the major pesticide users, start placing their orders in November and therefore pesticide sales companies need to start placing orders by July for as many as 100 products. This is also confounded by weather, particularly the distribution of rainfall. The practice of bringing sufficient chemicals to meet demand without carryover sometimes results in shortages of strategic pesticides which disappoint farmer-customers.

Pesticide companies reported that they sell more than 90% of their products directly to farmers through company-owned depots, salespersons and agents. The remaining 10% is marketed through retail outlets, stockists and trading stores.

Domestic pesticide companies identify pesticide products under development by scanning agrochemical magazines that report new molecules being developed and attending pesticide meetings such as the Brighton agrochemical conference. This permits pesticide companies to start development work and trials for registration before the products are commercialized as some molecules that work in Europe do not work in Zimbabwe while some molecules that work in Zimbabwe do not work in Europe. Once a company has tested a molecule locally and found it promising then it can negotiate a distributor agreement with the manufacturer and patent holder.

Because of the lack of capacities at the Department of Research and Specialist Services to conduct research and provide extension services, pesticide companies are increasingly providing advice to farmers on pesticide use and recover their costs by charging a levy between cost and selling price. Also, pesticide companies now spend money on advertising in farmer magazines and television during certain times of the year. Most distributing companies use company-employed representatives to promote their products to farmers. Competition is focused on price particularly for products coming off patents. Because of the intensifying competition, fertilizer companies have resorted to "tie-in sales" that give bonuses on chemicals if farmers buy fertilizers.

Because the Plant Protection Research Institute has a lack of vehicles and resources to police and enforce pesticide regulations, companies help the regulatory agency by policing the system and reporting violation to the Registering Officer for prosecution. The Agricultural Chemical Industry Association also provides training assistance to the regulatory agency. ACIA recently purchased a computer loaded with software to help PPRI with keeping registration records. Pesticide company representatives interviewed in this study indicated their belief that having government control on the actual registration of pesticides is better as the ACIA can have a commercial bias.

ACIA engages in public relations and holds meetings every year to educate pesticide users how correctly to use pesticides (KESWANI 1995). The organization works out a code of ethics for its members. It observes the International Code of Conduct on Distribution and Use of Pesticides and collaborates its safety education activities with the Global Crop Protection Federation (GCPF, formerly GIFAP). Recently, ACIA has published a handbook of available crop chemicals in Zimbabwe, a function traditionally carried out by the Department of Research and Specialist Services.

4.3.4 Performance

The Zimbabwean pesticide industry has performed well since 1992. Pesticide use increased tenfold from 250 to 2,424 tons from 1982 to 1992, despite severe cyclical droughts (SZMEDRA, 1994). The pesticide industry responded to this increase without accumulating redundant stocks because of tight allocation of foreign currency during the pre-ESAP era. The accumulation of redundant stocks did not occur during the ESAP period because the high interest rates were not conducive to speculation. In addition, the elaborate and comprehensive registration system prevented donors from dumping their chemicals as only registration holders can bring in chemicals. By contrast, Zambia, Malawi and Mozambique which lack registration systems have redundant stocks.

Although some products such as herbicides for grain crops fell behind the technological frontier in the 1980s, the industry has been rapidly introducing new products and getting back to the trend. The increase in competition is expanding the availability and range of pesticide products, thereby increasing farmers choice of these products. The packaging of pesticide has also improved in the last years, with significant savings in losses and spillage.

The liberalization of the industry has made the rate of increase in the prices of pesticides level off in nominal terms while the exchange rate of the Zimbabwean dollar has gone down (Annex 4-1). For example, the price of EDB has been unchanged for the past three years. In real terms pesticide prices have declined (Annex 4-2). The benefits of reduction in prices have been passed to farmers. The margins for pesticide companies have been squeezed.

Productivity in the industry is low because the plants are old. The drought also has affected productivity by deterring replacement of obsolete plant and equipment. As a result, there is a lack of high technology or change in equipment. Although pesticide companies carry out difficult formulations such flowable, wettable (dust), emulsifiable, granular, and dust pelletizing, which some years ago were as good as anywhere in the world, technologically-advanced countries have now moved to dry flowable formulation. Zimbabwe lacks this technology because the products are still on patents and the economies of scale are such that the minimum efficient plant scale is achieved by centralizing production in a country such as the United States and drawing supplies to other parts of the world from one plant. Even South Africa has still to move to dry flowable formulation.

As for employment, the pesticide industry still employs about the same number of people as were employed five years ago. The fertilizers and agrochemical industries employ nearly 1,000 workers. Despite the high interest rates which are putting pressure on pesticide companies to contain costs by reducing workers, companies have not started disinvesting in labor. This is because the pesticide sales are seasonal in nature and companies hire casual and part time workers.

4.4 Conclusions and recommendations

The pesticide industry is rapidly becoming competitive under the liberalization policies. Because of the increase in competition, companies are using price and non-price competition to defend and expand their market shares. Because of the intensifying competition, companies have increased the availability and range of products they offer to farmers, adopted better packaging, and trimmed profit margins. Consequently, the performance of the pesticide industry has improved. But labor productivity has not improved because companies continue to use old plants and employment has not expanded because the high interest rates are causing companies to contain costs and not hire as many workers as they would do since labor is one of the largest cost items.

Policy makers can continue to create incentives for expansion of the pesticide industry, facilitate entry by new players, and improve services to farmers and economic performance by implementing six policies. First, policy makers can adopt more liberal registration requirements for generic products and harmless products such as pheromones and biocontrol agents by reducing the trial period to one year and permitting the use of temporary registrations from other countries. Although generics and biocontrol agents still have to be registered because they are not always the same as original products the testing period can be reduced to a year. Second, the registration procedures need to focus on toxicity and leave efficacy to market forces and farmers choices among competing products. Respondents interviewed in this study expressed their belief that the government's Department of Research and Specialist Services needs to keep its regulatory functions because it has high moral ground when it comes to research and therefore can add accountability and respect to private research. However, the Department needs to reduce the time for registering pesticides from the present two years to within two months and reduce costs that farmers and pesticides companies are incurring waiting for approval of new products especially specialty products required to control specific problems. The Department of Research and Specialist Services needs to enforce regulations that what is labeled on sale is what is inside the package and prevent the dumping of off-strength chemicals in the country. The Department can finance its activities by improving the efficiency of registration, raising registration fees from the current ridiculously low Zimbabwe $450 to about ten times that figure, following up on products with expired registration, increasing charges for re-registration, and increasing penalty fees on violators of regulations.

Third, registration for generics should be by company and not by country and solvent as the Registering officer can easily check the authenticity and quality of the product by requiring the exporting company or country to certify its authenticity.

Fourth, companies importing already registered generic products should not be made to go through the three-year testing period.

Fifth, policy makers need to lower duties on pesticide raw materials to create incentives for local formulation and employment. Also, the customs procedures need to be streamlined to permit faster clearing of pesticide imports.

Sixth, policy makers can create better incentives for multinationals to invest in the research and development of products for this region by harmonizing registration procedures with other countries in the region. If Zambia, Malawi and Mozambique, which currently lack registration procedures, can be induced to adopt the Zimbabwean system then Zimbabwean firms can expand into those country markets as they will be better place to provide marketing services from this country.

Finally, policy makers can use the anti-dumping law under the General Agreement on Trade and Tariffs (GATT) to protect Zimbabwean pesticide industry from dumping rather than rely on rigorous pesticide registration procedures as current practice.

References

Keswani, C.L (1995): Environment friendly techniques of agrochemical use. Paper presented at the National Workshop on Agri-inputs marketing in a liberalized environment held at the Holiday Inn, Harare, 2 to 5 May, 1995. Harare: African Centre for Fertilizer Development.

Mudimu, G.D, Chigume, S. and M. Chikanda (1995): Pesticide use and policies in Zimbabwe: Current perspectives and emerging issues for research. Hannover: Institute of Horticultural Economics, Universität Hannover.

Scherer, F.M., and R. David (1990): Industrial market structure and economic performance. Boston: Houghton Mifflin.

Szmedra, P. (1994): Pesticides and the agrichemical industry in Sub-Saharan Africa. Report prepared for Division of Food, Agriculture, Resource Analysis, Office of Analysis, Research, and Technical Support, Bureau for Africa. Washington: United States Agency for International Development.

United Nations Industrial Development Organization (1986): The Manufacturing Sector in Zimbabwe. Harare: Regional and Country Studied Branch, Studies and Research Division.

Annex 4-1: Nominal Pesticide Prices (1989 - 1996)

Nominal ZW$/unit									
	Unit	1989	1990	1991	1992	1993	1994	1995	1996
HERBICIDES									
Atrazine 80%	kg	0.34	0.87	0.86	0.87				
Atrazine 50 FW	lt				1.59	1.71	1.90	2.15	2.42
Banvel	lt		15.20	18.22	38.80	54.40	55.20	55.20	62.00
Basagran	lt	1.81	1.73	2.44	5.64	5.64	7.00	6.48	7.50
Bladex	lt	0.90	0.90	1.48	3.48	4.05	4.62	4.75	5.25
Cotoran 80Wb	kg	1.50	1.69	1.90	4.64	5.90	7.81	7.81	7.50
Diuron 80%	kg	0.89	0.89	1.30	2.66	3.30	4.42	4.73	5.74
Dual 720 EC	lt	1.70	1.80	2.38	2.64	3.16	4.14	4.20	5.00
Gramoxone	lt	3.80	4.70	7.06	12.98	14.42	16.40	16.40	19.20
Igran 500 FW	lt	4.53	4.53	9.67	13.20	16.10	19.00	20.00	23.80
M.C.P.A.	lt	0.44	0.51	0.51	1.90	2.08	2.16	2.70	3.05
Sencor 480SC	lt					17.70	17.70	18.95	21.52
Tillam	lt	0.85	0.97	2.50	3.09	3.71	3.70	5.29	6.44
Trilfluralin	lt	0.70	0.70	1.16	2.04		2.45	3.05	3.81
INSECTICIDES									
Agrithrin	lt		4.31	4.24	8.75	6.20	6.90	6.90	6.90
Cabaryl 85%	kg	0.67	0.84	1.75	3.13	4.40	4.20	4.40	5.18
Chlorphyriphos	lt	2.22	2.85	3.65	6.88	6.73	6.85	6.85	7.20
Dimethioate 40	lt	2.67	3.43	4.77	9.05	9.60	9.50	11.60	14.28
Dipterex 2.5%	kg	0.04	0.04	0.07	0.14	0.19	0.33	0.42	0.47
Dipterex 95	kg		0.96	1.44	1.44	5.20	5.60	6.89	8.72
Hostathion	lt	9.69	10.24	15.92	32.37	37.14	32.20	49.92	62.22
Fanvelarate	lt						27.20	30.00	30.00
Metasystox	lt	4.40	4.90	6.80	12.80	12.98	15.60	15.60	23.20
Monocrophos	lt	0.04	1.66	2.05	3.11	3.85	4.43	3.90	4.13
Tedion	lt	0.53	0.53	0.71	1.26	1.46	1.82	2.22	3.10
Thiodan MO35	lt	3.23	4.21	5.41	11.30	17.60	14.86	19.56	20.20
Decis	lt					22.72			
Dursban	lt						6.80	7.00	7.39
Karate	lt							35.80	42.40
Marshal	lt								7.60
SEED DRESSING									
Baytan 15%	kg		64.00	100.0	145.0	145.0	146.5	146.5	146.5
Brassicol	kg		0.92	2.07	3.95	3.95	6.00	6.00	6.00
Gaucho	g						19.97	19.97	26.75
Innoculant	unit	1.50	1.50	2.00	2.00	2.00	2.00	12.51	11.81
Rizolex	kg				1.19	4.96	3.60	6.93	8.37
Thiram	kg	0.33	0.69	0.77	1.33	1.59	1.81	1.81	1.81
Vitavax Plus	lt				4.00	5.50	5.64	6.00	6.00
SOIL FUMIGANTS									
EDB ec	lt	0.61	0.73	1.03	1.73	1.65	2.05	2.03	2.50
Methyl Bromide	g	0.01	0.02	0.02	0.03	0.05	0.06	0.07	0.08

FUNGICIDES									
Bacemul	lt					2.00	4.00	2.00	2.00
Benomyl	kg	1.23	1.23	1.98	4.22	7.56	7.00	7.53	6.00
Bravo	lt	0.97	1.11	1.11	4.49	4.67	5.75	6.29	7.13
Copper Oxychloride	kg	0.21	0.25	0.28	0.40	0.43	0.63	0.89	1.02
DithaneM45	kg			4.32	11.13	11.13	14.92	16.00	18.65
Flolicur 250EC	lt					80.00	80.00	80.00	98.40

Source: Economics and Inputs Department, Commercial Farmers' Union

Annex 4-2: Price Increase of Pesticides in % (1989 - 1996)

% Price Increase									
	Unit	1989	1990	1991	1992	1993	1994	1995	1996
INFLATION		*12.90*	*17.40*	*23.30*	*42.10*	*27.60*	*22.30*	*22.60*	*21.40*
HERBICIDES									
Atrazine 80%	kg		60.54	-1.22	1.21				
Atrazine 50 FW	lt					6.87	10.00	11.63	11.07
Banvel	lt			16.58	53.04	28.68	1.45	0.00	10.97
Basagran	lt		-4.54	29.16	56.66	0.00	19.50	-8.11	13.67
Bladex	lt			38.96	57.63	13.99	12.27	2.79	9.52
Cotoran 80Wb	kg		11.08	11.18	59.07	21.32	24.48	0.00	-4.17
Diuron 80%	kg			31.20	51.22	19.39	25.41	6.46	17.63
Dual 720 EC	lt		5.58	24.43	9.77	16.46	23.66	1.44	16.00
Gramoxone	lt		19.15	33.45	45.59	9.99	12.07	0.00	14.58
Igran 500 FW	lt		0.01	53.13	26.71	18.01	15.26	5.00	15.97
M.C.P.A.	lt		13.64	0.00	73.18	8.43	3.94	20.00	11.48
Sencor 480SC	lt						0.00	6.60	11.94
Tillam	lt		12.75	61.31	19.01	16.68	-0.27	30.06	17.86
Trilfluralin	lt			40.01	42.83			19.84	19.86
INSECTICIDES									
Agrithrin	lt			-1.59	51.54	-41.1	10.14	0.00	0.00
Cabaryl 85%	kg		20.14	52.16	44.00	28.95	-4.76	4.55	15.06
Chlorphyriphos	lt		21.98	21.97	46.88	-2.25	1.82	0.00	4.86
Dimethioate 40	lt		22.22	28.15	47.25	5.7	-1.05	18.10	18.77
Dipterex 2.5%	kg		0.00	51.35	47.14	26.32	41.79	21.84	10.77
Dipterex 95	kg			33.56	0.00	72.31	7.14	18.77	20.94
Hostathion	lt		537	35.68	50.82	12.84	-15.3	35.50	19.77
Fanvelarate	lt							9.33	0.00
Metasystox	lt		10.20	27.94	46.88	1.39	16.79	0.00	32.76
Monocrophos	lt		97.35	19.23	33.99	19.16	12.99	-13.5	5.67
Tedion	lt		0.00	25.35	43.76	13.41	20.07	17.80	28.42
Thiodan MO35	lt		23.23	22.24	52.09	35.80	-18.4	24.03	3.17
Decis	lt								
Dursban	lt							2.86	5.21
Karate	lt								15.57
Marshal	lt								
SEED DRESSING									
Baytan 15%	kg			36.00	31.03	0.00	1.02	0.00	0.00
Brassicol	kg			55.23	47.71	0.00	34.17	0.00	0.00
Gaucho	g							0.00	25.36
Innoculant	unit		0.00	25.00	0.00	0.00	0.00	84.01	-5.93
Rizolex	kg					75.94	-37.8	48.0	17.20
Thiram	kg		53.06	10.54	41.97	16.08	12.14	0.09	0.00
Vitavax Plus	lt					27.19	2.48	6.00	0.00

SOIL FUMIGANTS									
EDB ec	lt		16.21	28.68	40.58	-4.55	19.51	-1.23	19.00
Methyl Bromide	g		44.69	8.64	29.08	48.85	23.35	11.76	10.52
FUNGICIDES									
Bacemul	lt						50.00	-100	0.00
Benomyl	kg			37.68	53.13	44.12	-7.94	7.04	-25.5
Bravo	lt		13.06	0.00	75.26	3.92	18.78	8.59	11.72
Copper Oxychloride	kg		14.35	12.43	28.84	8.13	31.33	29.47	12.66
DithaneM45	kg				61.17	0.00	25.42	6.77	14.21
Flolicur 250EC	lt						0.00	0.00	18.70

5 Pesticide Use Information Flows in Zimbabwe

Ray Kujeke[1]

Abstract

There is wide variation in the availability and use of information on pesticide use in developing countries. Zimbabwe has a relatively sophisticated pesticide registration and management system with formal requirements for local evaluation, registration and use. There are however a number of gaps and anomalies in the pesticide management information system leading to inadequate awareness and knowledge, especially at the critical user level. These include inadequate sources of unbiased technical information, the use of inappropriate channels in information dissemination and inadequate extension and training for field extension workers and applicators. There are minimal formal and informal linkages between public extension agents and the pesticide industry, and also with the registration and regulatory institutions. Zimbabwe is currently implementing major economic structural adjustment policies which have led to an increase in the number of traders, thus increasing the need for more resources for monitoring and regulation in particular and a review of the policies and regulations governing pesticide use in general.

This paper reviews the pesticide management system in Zimbabwe. It highlights the results of a survey which assessed the technical competence and attitudes of public extension workers, and the views and opinions of key players in the pesticide industry and the registration and other regulatory institutions. There is need for a review of the policies and practices of pesticide management and use to ensure greater access to technical and general information for all stakeholders. With the on-going market reforms, the information requirements and obligations expected of the key public and private institutions need to be increased and clearly defined.

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5.1 Introduction

The overall trend of increasing use of chemical control methods in developing economies requires closer attention by local stakeholders to ensure that the negative short and long term implications of pesticide use are adequately addressed. Environmental sustainability is one of the key challenges facing the agricultural production systems of developing countries. The efficient use of technology requires support from service institutions. Greater use of pesticides however increases the risks of negative impacts on all aspects of sustainability. Pest control and pesticide use in particular, is becoming increasingly complex, requiring the users, related institutions and the general public to have access to general and technical information with respect to a variety of issues. Little application of Integrated Pest Management (IPM) strategies in most developing countries has been attributed to a variety of factors, including the general lack of information and know-how of IPM practices within service institutions and at the user level.

The bulk of the technical information generated in the development of pesticides originates from developed countries. The relevant public and private institutions in less developed countries are generally not endowed with the necessary information and resources to participate fully in issues related to pesticide use. The debate on pesticide use has generally excluded the active participation of all stakeholders. Typically, the more pressing issues of food security and poverty alleviation have tended to overshadow the technical and health aspects of pesticide use. Even when pesticide use is debated, the focus tends to be on the costs and benefits, within the context of increasing agricultural productivity. Information on health and safety is usually secondary with minor obligations and liability on the manufacturers and retailers. Common strategies of information dissemination include short-term publicity campaigns and production of generic posters aimed at increasing public awareness. Such strategies are supported by the local pesticide industries, partly to indicate adherence to recommendations by international organizations like the WHO, and also as part of the industry's marketing activities.

This chapter describes and analyses the flow of pesticide management and use information among research, extension, vending companies and the end-users. It reviews the current and potential linkages, and the mandates of the various institutions involved in the generation, dissemination and consumption of information on pesticides. The chapter is divided into sections which cover the general issues first and examples from Zimbabwe where the information is available or applicable. General public awareness on pesticide use, and health and safety issues, is also reviewed. The chapter concludes with an assessment of and recommendations for a more comprehensive and efficient information system to enhance judicious, safe use and management of pesticides.

5.2 Pesticide use patterns in Zimbabwe

5.2.1 Pesticide use and regulation

As in other agriculturally based countries, the introduction of pesticides in Zimbabwe has provided a novel and relatively convenient technology for controlling and reducing pest damage. On a global scale, the volume of pesticides used in the country is insignificant. Zimbabwe however ranks amongst the major pesticide users in sub-Saharan Africa. Though erratic, the use of pesticides is increasing and the trend is likely to continue with the on-going shift towards a free market economy.

Most of the products are marketed through about 14 companies. About half of these companies are subsidiaries or franchised agents of transnational corporations. The active materials for all pesticides except copper oxychloride are imported, thus entailing the use of hard currency in procurement. Before the introduction of market reforms in 1991, the government was actively involved in the allocation of the foreign currency for importation of the pesticides or the ingredients.

The main institutions involved in pesticide registration are the Plant Protection Research Institute (PPRI) of the Department of Research and Specialist Services (DR&SS) in the Ministry of Lands and Agriculture, the Hazardous Substances Board (HSB), and the Drug Control Council (DCC) in the Ministry of Health and Child Welfare. The PPRI manages the registration of all pesticides, except those for use on animals that fall under the Drug Control Council. The Department of Agricultural, Technical and Extension Services (AGRITEX) in the Ministry of Lands and Agriculture is the major extension institution serving the communal and resettlement areas. The large-scale commercial farming sector, including state farms, are serviced mainly by the private sector.

The agricultural sector is the major user of pesticides with cotton and tobacco insecticides accounting for the bulk of the pesticides used. A fast growing market sector is in horticultural production. Small-scale commercial and the communal farmers account for less than 10% of the total pesticide sales.

Pesticide use tends to be erratic in the small-scale sector as the production systems are rainfed. About 15% of the estimated one million families in the communal and resettlement areas use chemicals or pesticides for pest and disease control on their crops (KUJEKE, 1993). Previous studies have indicated the lack of awareness of recommended technologies in general, and pesticide use in particular, as significant variables on productivity.

The official purpose of registration is to ensure the least hazardous and most efficient use for all sectors of the community (ALLCOCK, 1980). Information on efficacy and toxicity is the major requirement before registration. In addition, copies of the proposed label, advertisements and other promotional materials, and, samples of the pesticide have to be submitted to the registration institutions before final approval.

Before the market reforms, the procurement of pesticides was conducted through a government rationalization program aimed at controlling use of scarce foreign currency reserves. This program involved allocation of import licenses based on a priority list negotiated between the government and the association of pesticide companies, ACIA. The allocation of licenses was based on crude estimates of market shares and crop acreage. Because of the controlled market environment, companies cooperated intimately, and behaved as a classic oligopoly, to ensure that their common interests were represented. An active intertrade developed between the companies to maximize the foreign currency allocations and justify increases. With the on-going market liberalization the number of companies, which has already more than doubled, is likely to increase. There is no legislation to limit the entry of more firms onto the market. There are also no regulations limiting the number of brand names under which the same generic compound can be marketed by different firms.

The use of pesticides has come under greater scrutiny and critic from a more informed society and organized lobbying and pressure groups in developed countries. The availability of alternative pest control measures has strengthened the case for termination or controlled use of the more toxic compounds. More stringent legislation has also increased liability and induced risk-aversion measures among both marketers and users. This is not the case in Zimbabwe where the general public is typically uninformed and the majority of the end-users are semi-literate and unsophisticated in the technical, health and safety aspects of pesticide use. The market for pesticides in industrialized countries has stabilized and, in many instances the toxicity and volumes used have declined. The losses due to pests and pest damage, estimated at an average of one third of potential harvest, indicate the opportunity for increased productivity with increased pesticide use in developing countries. Because of the lack of readily available and affordable alternatives, or their perceived high opportunity costs, increased pesticide use still represents the main option for pest control in the agricultural production systems of most developing nations.

5.2.2 Sectors of pesticide use

The end-users of pesticides in Zimbabwe can be divided into four main groups (Table 5-1). This grouping is based more on the similarities of the users and less on the farming systems. The large-scale agricultural sector comprises mostly owner-operated commercial farms with a resident, formally employed labor force. Included in the group are the quasi-government farms managed by the Agricultural and Rural Development Authority (ARDA). The number of workers involved in pesticide application vary depending on the type and size of the enterprise, and on the application method used. At least four workers per farm are involved in application of pesticides per season. The knowledge and awareness of the operators is influenced by the attitudes of the owners and the practices used by the farm managers. For example the use or otherwise of protective clothing, depends firstly on whether the clothing is provided, and secondly whether there is follow-up supervision to ensure that the clothing is used as prescribed. Most types of pesticides are used on commercial farms. Application methods range from aerial spraying to use of hand-operated sprayers. Because of the high volume of business, and the consequent competition between traders, the commercial farms are able to attract the extension services of agricultural input suppliers and distributors.

The second group comprises small-scale commercial, resettlement and communal farmers who generally rely on family labor. The major pesticide group used is insecticides, which are sprayed mostly on cotton and tobacco. Application is usually by knapsack and ultra-low volume (ULV) sprayers. Extension services are provided by AGRITEX and sales representatives from the pesticide industry. Knowledge and awareness of pesticide use tends to vary amongst the applicators. Literacy is a key variable influencing knowledge as the most readily accessible information is in print form. Resource constraints and inadequate knowledge frequently result in modification of the recommended application rates and inadequate use of protective measures.

The third group is state control of nuisance pests. The main activities within this group are mosquito control by the Ministry of Health and Child Welfare, and tsetse fly control by the Department of Veterinary Services in the Ministry of Lands and Agriculture. Traditionally this has involved the use of DDT, with change only in recent years to the safer synthetic pyrethroids. Applicators in this group are state employees or casuals who are generally briefed on the potential dangers of pesticide misuse. The workers usually work under some supervision. State-run operations also include the use of acaricides for tick control on cattle in all communal and resettlement areas. This heavily subsidized service is run by the Department of Veterinary Services who purchase the acaricides and provide attendants to operate dip tanks in all the communal areas. A notable risk with acaricide use is the accessibility of the chemicals in the dip tanks to the public and wildlife. The fourth group comprises minor domestic use of pesticides in gardens, and for nuisance fly control mostly in urban areas. The products used are mostly low toxicity compounds which are available in off-the shelf, and usually ready to use packaging.

Table 5-1: Major groups of pesticide users in Zimbabwe

GROUPS OF PESTICIDE APPLICATORS	
a)	**Large-scale commercial and state farms:** Insecticides, herbicides, fungicides, acaricides and growth regulators on a variety of crops and livestock. Farm workers employed by commercial farmers and on state farms using tractor-mounted sprayers, knapsacks and ULV sprayers. Workers are also used as markets and assistants during aerial spraying.
b)	**Communal and resettlement areas:** Mainly insecticides and smaller quantities of herbicides and fungicides mainly on cotton and tobacco. Mostly family labor using knapsacks and ULV sprayers.
c)	**State Control:** Large scale control of nuisance pests including mosquitoes, tsetse fly, army worm. Also acaricides for tick control in all communal areas. Government employees and casual workers using aerial spraying, and knapsacks for mopping up operations.
d)	**Domestic Sector:** Small user group consisting mainly of insecticide sprays for household and garden pests, and also rodenticides. Aerosol sprays and hand-held sprayers using relatively less toxic compounds.

5.3 Management of agricultural information

Information and its management is critical for progress and influencing change. Information management and transfer is generally neglected in agriculture. Despite the extensive research indicating the inadequate flow of information between farmers, researchers, and extension workers there is still very little evidence of continuous interaction and collaboration.

Communication is still a neglected aspect of rural development in most developing countries. Information is a key empowerment and production factor equally important to the classic land, labor and capital. Accurate and timely agricultural information is generally unavailable or inaccessible to most rural communities. This so-called information poverty is characterized by perennial difficulties experienced in obtaining important marketing and technical information. A substantial amount of the information disseminated to rural communities is incompatible with the prevalent low or absent literacy skills among the recipients. Communication services to most rural areas tend to be inadequate or inappropriate. The majority of the inhabitants of the rural areas of Zimbabwe do not have ready access to basic communication facilities like postal and telephone services. Most of the rural and poorer urban communities cannot communicate other than through person-to-person contact. The adage of plenty of information but not enough communication still applies.

Examination of the flow of pesticide use information and gaps to the various players provides an opportunity for improving the pesticide management system. An effective pesticide information management system requires not only interdependence but also goal consensus.

As with other “imported” technologies, there is a usual assumption that once beneficial technologies like pesticides have been developed, interest and adoption are the next logical sequences; that is, if the product meets the specific user need for increased production or reduced losses, then it will create the necessary demand with minimal effort on information dissemination. Even when adoption occurs, there is limited adaptation and incorporation of local knowledge to develop situation specific and comprehensive national policies and regulations. New technology is not necessary if there is a gap between available knowledge and typical user practices. A major constraint in improving pest management in developing countries is the gap between the knowledge needed at the farm and that of which the farmer is aware.

5.3.1 Technology transfer

There is a limited knowledge base on the technology transfer systems of service organizations in developing countries. The key role of new technologies for improved productivity is generally well documented in formal research settings. The major shortcomings have been either the inappropriateness of the technology, and/or lack of compatibility between the technology and the environmental setting in which it is used. A common assumption in most technology transfer systems is that there is a natural, and inevitable unidirectional relationship between the formal research process and the process of transferring the research know-how and its adoption by end-users.

Technology transfer needs to be broadly defined to include the flow of technical information between the developers and users. The efficient use of pesticides therefore requires the development and dissemination of unbiased technical information. The information generated by the pesticide industry is biased towards promotion of the use of pesticides. As the industry is large and competitive, the players are likely to use more advertisements and engage in promotional activities to gain market shares. The pesticide industry is unlikely to actively participate in or support the development of alternatives to chemical control measures. Information on innovation like IPM therefore has to be promoted outside of the traditional industry network.

The debate on the impacts of the economic reform program in Zimbabwe has focused on key economic, financial and social issues. Structural adjustment programs have significant consequences for the technology transfer process. They are likely to induce technological regression in the agricultural production systems of resource-constrained producers. As reforms typically result in input price increases and market instability, the net effect tends to be reduced technology adoption as farmers become more risk-averse. Reform programs also increase the requirements for market and technical information as farmers have to learn to “shop around” for the most cost efficient methods of production and marketing. Comprehensive and timely information is unlikely to be found in the public service institutions. With limited access to information, farmers are likely to reduce or modify input usage.

5.3.2 Pesticide use information

The information needs of various stakeholders are different. Pesticide use is complex technology and most of the information is developed in the pre-registration phase, and that required for registration is typically too technical for the end-users.

Information is required by a variety of users for decision-making in pest management. Decision-makers in pest management in Zimbabwe can be divided into four main categories (Table 5-2). Within each category are the specific information requirements indicating the type of information needed, the reasons for the need and application. Assessment of information needs is a prerequisite for the identification of gaps. Analysis of the information needs of stakeholders in the pesticide management system also helps to identify constraints in the flow of knowledge and ways in which it might be improved.

Table 5-2: Categories of decision-makers in pest management

END-USERS
(Mostly farmers and farm workers)

*Cost-effective control
*Marketing and technical information
*Health and safety

REGISTRATION/REGULATORY
(PPRI, DCC, HSB)

*Policy and legislation
*Monitoring and regulation

EXTENSION SERVICES
(AGRITEX, Company Reps and others)

*Advisory service
*Education and training
*Monitoring

PRIVATE SECTOR
(Pesticide Companies & Retailers)

*Manufacturing and formulation
*Marketing and Research

End-users

End-users are the central decision-makers on pesticide use and practices. A number of factors influence the farmers decision-making on the most appropriate pest management methods. These factors include the farmers' perception of the pest problem, the cost of pest management options and the farmer's objectives. These and other factors ultimately influence the farmer's decision to use a pesticide and also the mode of application. There has been no systematic evaluation of end-user knowledge, attitudes and practices in Zimbabwe. Most training on pest management has been for cotton production. Fairly comprehensive training on cotton production is conducted by the Cotton Training Center, and over 7,000 extension agents and small-holder farmers have attended courses at the center since 1980. Establishment of threshold level before pesticide application is still a common problem amongst the cotton farmers in Sanyati and Gokwe communal areas (JOWAH, 1996 personal communication).

Choice of the most appropriate pest control method requires the correct identification of the pest. Pest identification is a key constraint in the adoption of pesticide companies and dealers. Large-scale users are generally supported by technical advisors from vending companies. The majority of the pesticide applicators are unsophisticated commercial farm workers and smallholder farmers with limited knowledge of the technical, health and safety issues related to pesticide use. Most applicators are generally not empowered to demand such information from employers, manufacturers and retailers, or from the other private and public institutions involved in the pesticide industry.

The major sources of pesticide use information for small-scale and communal area farmers are AGRITEX extension agents and sales representatives and distributors (KUJEKE, 1993). Small-scale users generally have limited access to the technical advisory services of pesticide firms. Typically they are unlikely to access more technical, health and safety information than that provided on the product label. Small-holder farmers tend to be skeptical of chronic pesticide poisoning.

Registration and regulatory services

The enforcement of pesticide legislation is a general problem throughout the southern Africa region (FAO, 1991). Most of the technical information available in registration and monitoring agencies emanates from the developers. Both the PPRI and the DCC require local evaluation of efficacy before registration. Local evaluation is conducted and sponsored by the applicant with the registration agency monitoring and evaluating the results. While this exercise has generally been conducted in good faith with reliable information generated, there are likely to be problems as “nontraditional” applicants enter the market. The registration agencies rely on toxicity data submitted by the manufacturers to support the registration application. This system has worked fairly well in the past, although there is the likelihood of abuse as more firms enter the pesticide business.

There are weaknesses in current policies governing the importation of pesticides by individual users. There are no records of the amounts of pesticides imported into the country by individual users. Problems are likely to arise as more farmers source for cheaper pesticides outside the country. As more companies enter the pesticide market the regulatory agencies' tasks and information requirements will increase. In the face of increasing human and financial resource constraints, the PPRI and the DCC are unlikely to fulfill this role adequately.

Though the PPRI has information on all the registered products dissemination to other interested parties is usually poor. For example only a few copies of the list of registered products listing brand names, active ingredients, the company and registration number are produced annually.

The HSB is responsible for classifying the toxicity of pesticides. A system of color codes (green, amber, red and purple) based on mammalian lethal dosages (LD) is used to categorize all registered pesticides. Retailers are obliged to keep a restrict sales of purple label products and to maintain a record of purchasers. There are also regulations on the required protective clothing for use in applying the four categories of pesticides.

Extension services

Field extension agents require a variety of pesticide use information to adequately address the needs of farmers. Information is needed on (a) symptoms of pest attack, (b) field diagnosis of pests (c) life cycles of pests, (d) pest frequency (e) pest movement between countries and regions, (f) survey methods, (g) data collection and processing, (h) safe and efficient pesticide use, and, (i) pesticide application methods. These information requirements are likely to be beyond the capability of the typical field extension agent. Extension agents also require information and knowledge on the hundreds of agro-chemical products available on the market. The difficulties of keeping abreast with products is compounded by the continual addition and withdrawal of registered pesticides. A survey of AGRITEX field extension agents in Midlands and Mashonaland Central Provinces, where pesticide use among communal and resettlement farmers is relatively high indicated that at least 20% of the respondents recommended a product that had been withdrawn from the market (KUJEKE, 1993). AGRITEX extension agents are provided with very little printed information on pest management by the research institutions. Most of the information on pesticide use, new products and technologies is developed and disseminated by representatives of the pesticide industry. Most of the materials are professionally prepared although the tend to be of questionable relevance and validity.

The pesticide industry

The identification, evaluation and final registration of a pesticide is generally long, rigorous and expensive. It involves huge investment in the primary and secondary screening research processes which are beyond the reach of most developing countries. Substantial technical and general information is accumulated in the process of development of a pesticide. The accumulation of data on a particular chemical begins in research institutions in the countries of origin. Due to the vast resources required from the initial identification to final registration and marketing, strong linkages have developed between various research and development institutions in developed countries to facilitate the development of safer and more efficient products. These institutions include academic, public and private research facilities cooperating and thus increasing the efficiency of evaluation.

The information generated during the initial screening and development of a pesticide is of immense value to the pesticide firms. Before registration of the compound this information represents intellectual property which can easily be imitated and duplicated by competitors. Because of the economic value of the technology, there is no culture of transparency in the accumulation and dissemination of pesticide information. After registration, this investment is protected through patent agreements. Patents do not offer foolproof agreements, and the technology can sometimes be easily imitated, for example though the production of isomers, to produce similar compounds with less investment. End-user developing nations do not have access to most of the technical information generated during development nor do they have the resources to fully cross-check the validity and comprehensiveness of the toxicity data submitted subsequently to support local registrations.

The short-run economic benefits of pesticide use are well documented. Information on the advantages of chemical control of pests is usually professionally prepared for the various categories of consumers by the multinational corporations who form the backbone of the pesticide industry. As the pesticide industry is a multi-billion dollar business, a substantial amount of the information generated is inaccessible to the public and researchers. Such information includes negative issues like carcinogenic or environmental effects that are likely to have long term ramifications on viability of the industry.

There are almost 40 companies involved in the formulation and marketing of over 500 registered agrochemical products (CHIKANDA, 1990) Most of the firms are affiliated to the Agricultural Chemicals Industry Association (ACIA). Companies require technical information primarily to support registration which is a prerequisite to marketing. There are consequently formal linkages and interaction between the companies and the registration institutions to facilitate the registration process. Pesticide companies also require information on user needs to support their product development and marketing activities. Linkages between pesticide companies and small-scale users are mostly weak and informal. They also produce technical and promotional materials targeted at end-users and support institutions. While the relevance and quality of these materials vary, it is typically slanted towards enhancing the company and/or the product image. A significant portion of the technical material disseminated by pesticide vending companies is biased.

Once registration application is approved, there are minor obligations on the part of the applicant to supply information. A major problem with the information provided by the pesticide industry is the proliferation of brand names. This is likely to confuse both the end-user and public extension agents, who may well be already familiar with the product.

5.4 Information sources

There is inadequate research on the information systems used by farmers in obtaining technical information. Lack of information, uncertainty, and perceived risk have been shown to inhibit decision-making at farm level. In general the farmers' main sources of pest management information are (a) research services, (b) government extension services, (c) the pesticide industry, (d) other farmers, and, (e) the farmers own experience (FARAH, 1994). In Zimbabwe the main pesticide research institution is DR&SS which coordinates pesticide evaluation through the PPRI, and weed and herbicide trials by the Agronomy Institute. Other research institutions, like the Agricultural Research Trust and the Tobacco Research Board also conduct evaluation trials. Government extension services are provided through AGRITEX which has a compliment of over two thousand personnel.

The pesticide industry is represented by multinational companies subsidiaries and agents and about 160 technical advisors and sales representatives. The technical advisors in the pesticide industry are usually technically competent in pesticide use and there is usually person-to-person communication with the large-scale users. Technical advisors generally do not serve the small-scale users in communal and resettlement areas. Overall, the main source of pesticide use information in Zimbabwe is the pesticide industry, which is generally well-supported by the parent multinationals. Pesticide firms produce the bulk of the printed materials on pesticide use, with less input on health and safety issues.

5.4.1 Farmer-AGRITEX linkages

Small-holder farmers use AGRITEX extension agents and sales persons as the main source of pesticide use information. The research institutions are generally inaccessible sources of pest management information for these farmers. The information disseminated by research institutions is generally incompatible with the level of comprehension within the rural communities.

Surveys conducted in Mashonaland Central and Midlands provinces indicate that field extension agents are generally knowledgeable on pesticide application skills and less knowledgeable on specific product knowledge. They generally rely on sales representatives, product labels and other printed materials for information about new products and techniques. Some of the small-holder farmers are well acquainted with the intricacies of pesticide application. AGRITEX agents however tend to have negative attitudes to farmers as source of technical information. At field level extension agents are likely to face problems of credibility as they are not the prime generators of the technology.

AGRITEX extension workers and supervisors undergo limited pre-service training in pests and pest management. Less than 4% of the department's operational budget is for staff training (KUJEKE, 1993). The Training Branch runs an in-house two-day course on the safe use of pesticides. This course is useful for raising awareness although it provides limited information on pest management in general, and alternatives to pesticide use in particular. Most of the information available to extension staff is through person-to-person contact with sales representatives and printed materials (including labels). AGRITEX extension agents have limited opportunities to attend the technical field days sponsored by marketing companies, to acquire or update knowledge and skills. With increasing budgetary constraints, and the growing concern over the cost-effectiveness of agricultural service institutions, AGRITEX is unlikely to have the capacity to take on extra responsibilities in pesticide management.

There is a limited research on farmer knowledge and practice to pest control and pesticide management. Large-scale farmers are generally well-supported by the industry and informed of various issues related to pesticide use. Within the small-holder sector pesticide use is mostly on cotton and tobacco, with erratic use on other crops. Pesticide use on horticultural produce is increasing. Farmer knowledge, attitudes and practices are likely to vary between and within the different sub-sectors.

A number of non-governmental organizations including the agricultural workers union, are getting more active in raising awareness of pesticides and alternative control methods. They are however unlikely to have a major impact as their coverage is limited. The agricultural workers union has also raised concern on the plight of some commercial farm workers involved in pesticide application. Informal surveys done on large-scale commercial farms indicate that a significant number of workers applying pesticides are not provided with pre-spraying instructions. This includes regular briefing on the hazards of eating, drinking and smoking. While the use of color codings and pictograms has helped to simple understanding of pesticide use safety requirements, the survey indicated only a minority of workers knew the correct order of toxicity of pesticides using the color codes.

5.4.2 Information channels

Choice of appropriate information involves more than mere common sense; it is a complex process that is influenced by the interplay of messages, symbols and contextual influence. While person-to-person communication is media rich and the most ideal, it is not practical given the location and number of pesticide users. There are concerns and problems related to competence and credibility of extension agents who are better placed to provide information to the small-holder farmers. Literacy is a key constraint in the small-scale sector. Although product labels for products targeted for the small-scale users are printed in the vernacular languages, research has indicated that messages carried in posters are generally not understood by farmers (ESCALADA and KENMORE, 1988; MUTIMBA, 1980). The technical nature of pesticide information, for example with respect to application procedures, requires basic mathematical skills.

Other media channels, like radio and television are not used on a regular basis for dissemination of information. Radio in particular offers opportunities for low cost dissemination of general and awareness type information. There is generally no formal, systematic use of mass media channels for transmission of information. The effects of this gap are likely to increase as pesticide use expands in the small-holder farming sector.

5.5 Public awareness

There is a paucity of research on public knowledge and awareness with regard to pesticide use and management in Zimbabwe. Specifically little is known about the knowledge of pesticide dangers and attitudes to pesticide use. The common reference to pesticides, for example *rogor* (dimethoate) does indicate some knowledge of the potential dangers. Cases of pesticide poisoning through use of empty containers seem to be on the decline. Chronic poisoning is however likely to be less familiar. There is still a gap between the knowledge available to the pesticide industry and registration and monitoring agencies on the one hand, and the general public on the other. The public have easy access to all (except purple label products) registered in the country. Green and amber label products are readily available in general stores and supermarkets. The only information on safe and effective use is that provided on the product label.

Figures compiled by the Government Analyst Laboratory indicate a total of 513 sudden deaths for the period 1986-1990 attributed to pesticides (Government Analyst, 1990). These figures, which include accidental, suicide and homicide cases, are conservative as only the cases where a sample is taken for laboratory analysis are recorded. Cases in remote rural areas are likely to go undetected or prove too cumbersome to investigate. These figures represent only acute poisonings. Levels of chronic poisoning are difficult to estimate. These cases of death and serious poisoning from pesticides indicate the need for sustained training and awareness of the hazards of pesticides. They also point to a possible weakness in the regulations on availability of pesticides for malicious purposes. In general there is no legislation on retailing pesticide products; any registered dealer can procure and sell pesticides.

The Department of Occupational Safety, Health and Workers Compensation in the Ministry of Labor and Social Welfare collects data on pesticide poisonings in the industry and on commercial farms. Their activity programs include safety surveys, and the production of print materials on all aspects of occupational safety. The department has also been active in publishing the occupational hazards of pesticide use among agricultural workers. The figures are therefore limited to work related poisonings. Generally only cases of acute poisoning are reported and considered for compensation purposes. Cases of chronic poisoning are difficult to prove.

There is a need for a more formal system of dissemination of information on pesticides to consumers. Typically consumers are uninformed of the pesticides used for agricultural produce. Of major concern is the designated waiting period before harvesting and consumption. Pesticide residue on produce is not monitored. No public institution has the mandate for ensuring the safety of food products marketed and consumed. Responsibility for monitoring is spread among a number of public institutions.

The pesticide industry sponsors awareness campaigns promoting the safe use of pesticides. The industry association, ACIA, also sponsors a regular newsletter, promoting the safe use of pesticides and the business interests of the members. The consumer lobby group Consumer Council also occasionally published pesticide safety articles in the press (for example The Herald, 5 January 1996). Awareness campaigns are a short-term measure and generally do not result in long-term behavior changes. The Drug and Toxicology Information unit at Parirenyatwa Hospital provides information for handling pesticide poisoning, mainly for medical personnel.

5.6 Conclusions and recommendations

Effective use of technology requires knowledge on the part of users and advisors. The increasing use of pesticides entails a greater demand for more and specialized services. There are numerous stakeholders in the use and management of pesticides. An efficient and sustainable system of pesticide management has to accommodate the perspectives, interests and needs of all the diverse individuals and organizations. The on-going market reforms will lead to an increased number of firms in the marketing of pesticides. The goodwill and self-regulation exhibited by pesticide firms is likely to be eroded. The overall policy framework needs to be reviewed to ensure that the monitoring and regulatory agencies are empowered with the necessary authority to enforce legislation.

There is evidence to indicate that government intervention through regulations and taxation is an incentive for pesticide users to consider the negative effects (FARAH, 1994). In the absence of such intervention, pesticide use is likely to be excessive from society's point of view even though the level of usage at individual level would seem to be perfectly logical from their perspective.

Pesticide use and management requires the development and implementation of a locally relevant and realistic model of technology transfer that recognizes and simplifies the mass of complex information generated in the development and use of pesticides. This will encourage end-users, service institutions, other local organizations and the general public to become active players and transferers of information.

Compared to other Sub-Saharan countries, the pesticide registration system in Zimbabwe is stringent and well-managed. There are some inadequacies which are partly due to irregular monitoring and update of policies and regulations especially in the light of the on-going economic reforms.

The resource constraints facing public institutions need to be considered in the analysis and possible amendments of policies on pesticide use. The public institutions in Zimbabwe are under pressure to be more cost-effective. They are likely to implement cost-cutting measures which may result in delegation of some of their activities to other public institutions or to the private sector.

The following recommendations are made:

a) Regulation and Monitoring Agencies (PPRI, DCC, HSB)

- Updating the Handbook on Registered Pesticide: The updating of the pesticide handbook is long overdue. This would allow extension agents and farmers to have information on the various products registered, methods of use and the types of crops for which the product is registered. While this exercise could be supported by the pesticide industry, it should be led by the PPRI or other public institution.
- Maximum levels of pesticide residues in food products should be set and published for use. This will facilitate regular monitoring by health inspectors and other interested parties.
- Increasing the required registration information: With the increasing number of firms involved in marketing, sourcing of products and active materials will become an important marketing activity which requires monitoring. Information on the source of materials is useful as some products do not meet specifications and quality standards.
- Information submitted for registration should be disseminated to other institutions. The regulations may need to be reviewed to ensure that for products targeted for the small-holder sector, some of the technical, health and safety information is submitted to AGRITEX after approval.
- Introduction of accreditation scheme for end-users: In the long-term it would be ideal to have an accreditation scheme to ensure that extension agents and applicators have a minimal level of competence in pest management and pesticide use. For the short-term this scheme could be limited to applicators using the more toxic compounds and extension officers directly involved in training.
- Limitations on brand names for generic products: The use of different brand names especially on some generic compounds creates confusion. A limit on the number of names under which the same products can be marketed has to be set. This will ensure that end-

users and extension agents can keep up with the hundreds of products now available. Information on brand name products could indicate similar products.

- Production of print information for extension agents: The registration agents should provide more support in the production of print material for extension agents. This includes checking the technical merits of information provided for extension agents and farmers.
- Obligatory reporting of all cases of poisoning to PPRI/DCC: The registration institutions need to keep a directory of cases of poisoning on human, domestic pets and wildlife. This information is vital in assessment of the prescribed uses and possible restrictions of some registered products.
- Vetting of all advertising and promotional materials targeted at small-holder farmers: All advertising and monitoring materials should be assessed by the registration institutions. Some of the promotional materials deliberately omits some information or exaggerates the product efficacy.
- More efficient monitoring of efficacy trials: PPRI and DCC do not have the capacity to fully participate and monitor pesticide evaluation. The industry association could be invited to coordinate trials and act as a self-regulator to ensure that evaluation is systematic.
- Checks on quality of pesticide products.
- Early publication and dissemination of product information: Publication and dissemination of information on new products, withdrawn products, etc.

b) Extension Agencies

Training

- Inclusion of pest management and pesticide use in agricultural college curricula. The curriculum for most agricultural colleges does not have a core course in pest management. This would be useful for training in alternative control methods including IPM.
- Upgrading of pesticide use course to obligatory for extension staff involved in providing advisory services.
- Design of a comprehensive course for technical and field staff serving farmers as the major pesticide users; this could be linked to accreditation.

- Involvement of the pesticide industry in training.

Extension

- Use of multi-media strategies to maintain awareness and knowledge (increased use of electronic media)
- Delegation of some extension functions to pesticide companies: Encourage and formalize participation of the pesticide industry in conducting pest and pesticide management courses e.g. the safe use course at Domboshawa
- For products targeted at small-holder farmers, include the participation of AGRITEX agents in evaluation and demonstration trials
- Compilation of cases of pesticide poisoning to human and wildlife
- Provision of protective clothing for field extension staff
- More liaison with other institutions.

c) Farmer

- Restriction on the use of Purple Label products unless accredited
- KAP (knowledge, attitude, practice) studies among different farming groups
- Greater publicity on consequences of pesticide misuse.

d) Industry

- Formal training and accreditation of sales staff
- Provision of generic health and safety information
- Provision of protective clothing to AGRITEX extension agents

Glossary

Communication - the process of creating shared meaning among two or more people through verbal or non-verbal transaction.

Electronic media - used broadly to refer to radio, telephone, television and computers.

Formal channels - official paths of messages/information flow prescribed the source.

Informal channels - unofficial and informal networks "the grapevine" used for transmission of messages and information flow.

Information channel - a means of passage, for example verbal, print or electronic media, for transmitting a message from one point to another.

Information flow - the transmission of messages between two or more persons, or, discrete points in a system.

Information source - a person or point of origin, such as an individual or organization, that provides or initiates a message.

Information Technology (IT) - computer based technology and telecommunications video, radio, CD-ROM and other computer applications.

Media richness - the capacity of a medium to facilitate shared meaning. Rich media (for example face-to-face communication or telephone) has the highest capacity to facilitate shared meaning. Lean media (newspapers or journals) has the lowest capacity.

Technology transfer - in a broad sense, information that is put to use.

References

Agritex (1985): The safe use of pesticides. Agritex Training Branch. Harare: Agritex.

Allcock, S. and Leece, V. (1980): Handbook of registered pesticides (excluding herbicides) in Zimbabwe. Plant Protection Research Institute: Department of Research and Specialist Services (DR&SS). Harare: DR&SS.

Ah, N.S. (1989):Science and technology information transfer in developing countries: Some problems and suggestions. Journal of Information Science, 15:81-93.

Barghouti, S., Cromwell, E. and Pritchard, A. (eds), (1993): Agricultural technologies for market-led development. World Bank Technical Paper no.204. World Bank: Washington D.C.

Chikanda, M. (1990): quoted in Mudimu, D.G., S. Chugume and M. Chikanda (1995): Pesticide use and policies in Zimbabwe - Current perspectives and emerging issues for research. Pesticide Policy Project Publications No.2, University of Hannover, Germany.

Escalada, M. and Kenmore, P. (1988): Communicating integrated pest control to rice farmers at the village level. In: Pesticide Management and Integrated Pest Management in South-East Asia (eds. P.S Teng and K.L. Heong). Maryland: Consortium for International Crop Protection, pp. 221-228.

FAO, (1991): Sub-regional workshop on pesticide management for SADCC member states. Harare, 20-27 May 1991. FAO/SADCC, Accra, Ghana, 1991.

Farah, J. (1994): Pesticide policies in developing countries: Do they encourage excessive use? World Bank Discussion Paper n° 238. World Bank, Washington D.C.

Government of Zimbabwe (1990): Government Analyst Report. Government Printer: Harare.

Kujeke, R.T. (1993): Pesticide use information flows and competencies of Agritex extension agents in the Midlands and Mashonaland Central Provinces of Zimbabwe. Doctoral dissertation, Michigan State University, East Lansing, USA.

Kujeke, R.T. (1994): Pesticide use information flows and competencies of public extension agents in Zimbabwe. In Proceedings of the 10th Annual Conference of the Association for International Agricultural and Extension Education. Arlington, Virginia March 24-26 1994. AIAEE.

Mutimba, J. (1980): Understanding the instructions on pesticide labels. The Zimbabwe News, 4 (6): pp. 139-141.

NRI (1992): Integrated pest management in developing countries. Experience and prospects. Consultants report commissioned by the Integrated Pest Management Task Force. Chatham: Natural Resources Institute.

Nhachi, C. and Kasilo O. (eds.) (1996): Pesticides in Zimbabwe: Toxicity and health implications. University of Zimbabwe Publications, Harare.

Pimentel, D., H. Acquay, M. Biltonen, P. Rice, M. Silve, J. Nelson, V. Lipner, S. Glordano, A. Horowitz and M. D'Amore (1992): Environmental and econominc costs of pesticides use. BioScience, Vol. 42, pp. 750 - 760.

Repetto, R. (1985): Paying the price: Pesticide subsidies in developing countries. Washington D.C: World Resources Institute.

Trevino, L., Daft, R. and Lengel, R. (1990): Understanding managers' media choices: A symbolic interactionist perspective. In Fulk, J. and Steinfeld, J. (eds), Organizations and Communication Technology. California: Newbury Park.

Zijp, W. (1994): Improving the transfer and use of agricultural information. A guide to information technology. World Bank Discussion Paper no.247. World Bank: Washington D.C.

6 Economics of Pesticide Use in Zimbabwe Agriculture

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Abstract

This paper analyzes economic factors that have affected the level of use of pesticides in Zimbabwe agriculture. Specifically, the paper discusses the effects of price, risk, credit availability and cropping mix choices as factors affecting levels of pesticide use. Tentative estimates are also made of the degree of price responsiveness as well as inferences on the efficiency of use of pesticides in Zimbabwe.

The results of this study indicate that pesticide usage has been responsive to prices and the response has tended to be price inelastic. The results show that 10% increase in the price of insecticides, holding product and other input prices constant would on average yield 2.34% decrease in use of insecticides. Similarly, a 10% price increase for herbicides, fungicides and other pesticides would yield, respectively, decreases of 2.45, 2.65 and 3.24%. This result is important in that if the government wished to reduce pesticide usage using levies the results may not be very dramatic. Estimates of values of marginal product for insecticides, fungicides and herbicides, tend to suggest that on the whole Zimbabwe has been an efficient user of pesticides, with values of marginal products being on average different from prices by 5%.

This paper argues that the observed heavy use of pesticides in commercial relative to communal sectors can be attributed to a number of characteristics of these sectors. Commercial farmers have better access to credit, are in better agroecological regions, have better access to water and hence have lower yield risk; all properties associated with high pesticide availability or use. The advent of the Economic Structural Adjustment Program (ESAP) in 1991 widened the gap in these characteristics between communal and commercial farmers.

This chapter gives a broad overview of factors affecting pesticide use in Zimbabwe. Most factors affecting pesticide use, however, can only be assessed through farm level analysis of farmer decision making processes with regard to applications of pesticides.

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6.1 Introduction

This chapter evaluates the contribution of different factors to use of pesticides in Zimbabwe's farming communities. In particular we look at the impact of price, risk, availability of credit and cropping patterns on pesticide demand.

Zimbabwe's farming sector is dual in nature. On one hand we have large scale highly sophisticated commercial farms in agro-ecologically very favorable parts of the country, and on the other small scale resource poor smallholder farmers in marginal areas. It is estimated that in 1992 the smallholder sector consumed about 18 percent of all pesticides utilized in Zimbabwe with the remainder going into large scale commercial agriculture (SZMEDRA, 1994). Because of this duality factors affecting the sub-sectors' demand for pesticides are bound to differ.

This chapter is arranged as follows: the next section gives a theoretical discussion of factors affecting levels of use of pesticides by farmers; section 6.3 gives the state of pesticide use, price responsiveness and efficiency; section 6.4 discusses trends in prices and sales of pesticides; section 6.5 discusses the cropping mix-demand relationship; section 6.6 analyses the relationship between risk and pesticide demand; section 6.7 looks at credit availability and pesticide demand; and finally section 6.8 summarizes and concludes the discussion.

6.2 Determinants of pesticides use

6.2.1 Price

Pesticides differ from other inputs involved in the agricultural production process. Whereas inputs such as fertilizer and water directly impact output, pesticides impact productivity indirectly through their toxic effect on yield reducing pests (LICHTENBERG and ZILBERMAN, 1986). One way of looking at this is that directly productive inputs determine the potential output. Attainment of this potential is affected by prevalence of pests. Applications of pesticides determine the degree of damage from pests or to what extent we attain the potential output. If pest prevalence is low, then application of pesticides will also have little impact on observable yield. Alternatively, when infestations are high applications of pesticides will have very significant positive impact on yield. Therefore, demand for pesticides is bound to be very price responsive in production processes that are subject to heavy pest infestations as compared to those with less pest prevalence.

6.2.2 Risk

Different forms of risks faced by farmers in their work have an impact on levels of use of pesticides. In making decisions about what levels of pesticides to use, more often than not farmers are uncertain about what level of pest infestations they are facing. Even if they can accurately estimate infestation levels they still face the uncertainty of the level of mortality their applications will effect. The greater these two types of risk are, the higher the level of application risk averse farmers will make (PANNELL, 1991).

Other forms of risk also have an impact on farmers levels of pesticide use. Uncertainty about output price and yield leads to uncertainty about how much the farmer would get from his/her production. If a farmer applies excess amounts of pesticides and the revenue from his production turns out to be low due to lower than anticipated yield or prices, the farmer runs the risk of poor profits. To guard against the probability of very poor profits a risk averse farmer would tend to under apply pesticides (PANNELL, 1991).

Compounding the above, is the degree of risk aversion itself. The degree of risk aversion is dependent on wealth status of the farmer (BUNN, 1984). Poor farmers are more likely to be more risk averse compared to wealthier farmers. A response to all the different types of risk discussed above which can be adopted by farmers is production diversification. Poorer farmers, because they are more risk averse, are likely to sacrifice higher expected profits for lower risk exposure. An important consideration of poor farmers is safety first when it comes to food for subsistence.

6.2.3 Intercropping

In most of Southern Africa intercropping is a common production practice. The most important crops intercropped with major grain crops are pumpkins, water melons, okra and pigeon peas. These crops play a very important part in household nutrition providing relish and supplementary bulk food during the lean pre-harvest period. Intercropping usually involves a mixture of grass and broad leafed plant species. Since most herbicides are designed to target one of these types of species, their use in intercrops become counter productive. To get the maximum benefits of pesticides, especially herbicides, one has to mono-crop.

6.2.4 Credit availability

One of the most limiting factor in the use of modern inputs in African agriculture is lack of credit. Paramount in this problem is the issue of land tenure which in certain sectors precludes the use of land as collateral to secure credit. The credit constraint is important in pesticide use due to its need for capital investment in application equipment in addition to financing purchases of the chemicals themselves. Thus the degree to which credit is limiting has an effect on pesticide use levels.

6.2.5 Value of marginal product of pesticides

LICHTENBERG and ZILBERMAN (1986) suggest a production function that distinguishes between productive and protective inputs of the form

$$Q = \alpha Z^{\beta} [G(X)]^{\gamma}$$

where Q is output;

Z is level of productive input use;

X is level of pesticide use; and

G(X) is the pest damage control function, achieved from applying X amount of pesticides; and α and β are production parameters.

The function G(.) equals zero if no pesticides nor any other damage control measure are utilized and equal to one if pesticides are used at a level enough to kill all pests. If G(.) is equal to 1 we achieve the maximum output for the given level of productive inputs and this gradually decreases as less and less of pesticides are used.

Assuming a logistic damage control function and the neoclassical profit maximization objective on the part of farmers, LICHTENBERG and ZILBERMAN derive the following relationship for pesticide demand and value of marginal product:

Pesticide demand: $X = a0 + a1 \ln (PQ / w)$

Value of Marginal Product: $VMP = PQ \exp\{- (X - a0) / a1\}$

6.3 Pesticide use in the Zimbabwe arable sector

Data on pesticide use in Zimbabwe is very sparse and, when it exists, is very aggregated. The Ministry of Agriculture data series which was updated by MUDIMU et al. (1995) reports value and quantities of sales of insecticides, fungicides, herbicides, and other pesticide sales from 1986 to 1994. Table 6-1 summarizes for these chemical aggregates the quantities and their average prices in 1993 Zimbabwe dollars. Also reported in Table 6-1 are total values of crop production in 1993 Zimbabwe dollars.

6.3.1 Demand

Table 6-2 reports aggregate demand function estimates for insecticides, fungicides, herbicides and other crop chemicals using specification in section 6.2.

Table 6-1: Sales and average prices of pesticides (in 1993 ZW$)

Year	Insecticides		Herbicides		Fungicides		Others		Crop value
	quantity in (t)	price/kg	quantity in (t)	price/kg	quantity in (t)	price/kg	quantity in (t)	price/kg	1993 ZW$
1986	2867	56.57	1007	93.82	402	84.22	446	35.42	4844.65
1987	2599	42.00	800	90.61	339	62.26	398	32.80	3578.29
1988	2641	43.01	924	85.84	416	72.39	470	29.69	4403.24
1989	2586	45.48	876	85.05	410	78.72	363	38.37	4283.46
1990	3075	26.82	1037	51.02	450	43.46	536	17.54	3721.01
1991	3382	21.30	1140	40.58	495	34.56	590	13.88	4477.74
1992	3551	20.62	1197	39.35	520	33.40	620	13.39	2914.35
1993	3374	23.27	1138	44.38	494	37.85	589	15.11	3000.00
1994	3205	33.42	1081	63.67	494	51.61	559	21.77	3147.62

Source: MUDIMU et al. (1995)

Table 6-2: Pesticide demands estimates

Pesticide (tons)	Constant (a0)	Natural log (Revenue / pesticide price) (a1)	Coefficient of determination
Insecticides	-5182.5 (-2.66)	710.29 (4.21)	72
Herbicides	-1757.7 (-2.91)	245.63 (4.60)	75
Fungicides	-866.8 (-3.13)	118.4 (4.75)	76
Others	-1456 (-4.75)	164.5 (5.67)	86

Source: Own calculations
Note: Numbers in parentheses are t-statistics

Results from Table 6-2 indicate that the demand specification shows remarkable fit with model explaining at least 72% of the variation in pesticide use. The critical t-statistic for the hypothesis that the ratio of revenue to pesticide price does not affect pesticide use levels is 2.365 for 95% confidence and 1.895 for 90% confidence. Based on these critical t-values all parameters estimated are significantly different from zero at both 90% and 95% confidence levels. This implies that at aggregate level the Zimbabwean farmers significantly respond to prices in their pesticide usage. The degrees of price responsiveness are reported in Table 6-3.

Table 6-3: Pesticide demand elasticities at the means

Pesticide	Price elasticity of demand
Insecticides	-0.234
Herbicides	-0.245
Fungicides	-0.265
Others	-0.324

Source: Own calculations

Results reported in Table 6-3 indicate that demand is relatively price inelastic since absolute values of elasticity for all pesticides falls short of one. The results show that an 10% increase in the price of insecticides, holding product and other input prices constant would on average yield 2.34% decrease in the use of insecticides. Similarly, a 10% price increase for herbicides, fungicides and other pesticides would yield, respectively, decreases of 2.45, 2.65 and 3.24%. This result is important because if the government wished to reduce pesticide usage using levies the results may not be very dramatic.

6.3.2 Marginal productivity of pesticides

One way of assessing efficiency of the pesticide use is to estimate the value of the marginal product of pesticides. If the value of marginal product is equal to the price of pesticide, further increase in the use of pesticide will not increase profits. If the value of the marginal product is greater than the pesticide price increase in pesticide usage will increase profits. Conversely, if the value of the marginal product is less than price, a decrease in pesticide usage increases profits. More compactly, a deviation of the value of the marginal product from price represents inefficient use of pesticide. Table 6-4 reports values of marginal products evaluated at the means of pesticide data for the years 1986-1994 using the formula for VMP in the preceding section.

Table 6-4: Value of marginal product 1986-1994

Pesticide	Value of marginal product (1993-ZW$)	Pesticide price (1993 ZW$)
Insecticides	48.659	51.430
Herbicides	93.056	97.911
Fungicides	78.260	82.280
Others	33.640	35.964

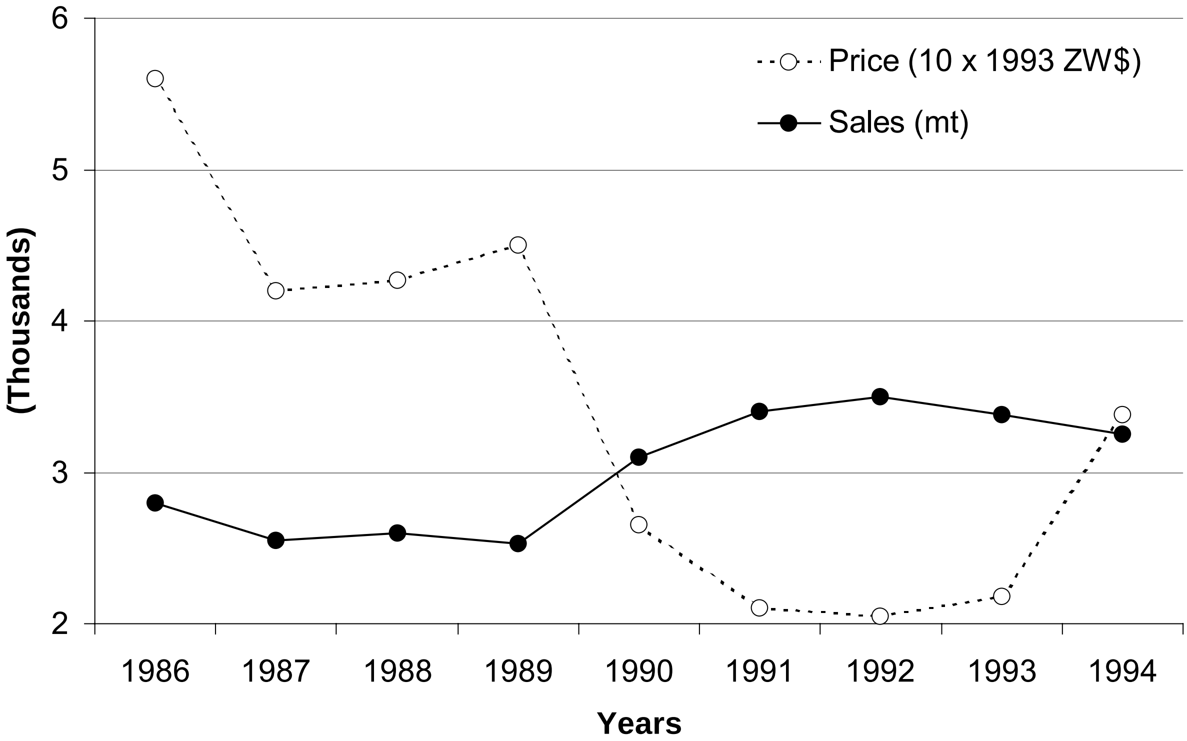
Source: Own calculations

For all groups of pesticides the values of marginal products are remarkably close to prices. For insecticides, herbicides and fungicides values of marginal products are around 5% less than prices. These results tend to imply that on aggregate Zimbabwe farmers have been efficiently utilizing pesticides.

6.4 Trends in sales and prices of pesticides

The preceding section estimated the demand responsiveness of the Zimbabwe farming community to prices of pesticides. This section reviews trends in sales and prices to gain a picture of intertemporal behavior. A number of factors had significant impact on prices of pesticides between 1980 and 1994. Before 1991 the chemicals industry was highly concentrated and importation of raw materials tightly controlled by government. After 1991 exchange controls have been loosened and the number of firms involved as well as the number of products have increased. In the proceeding we examine the effects of these factors on prices and demand for pesticides.

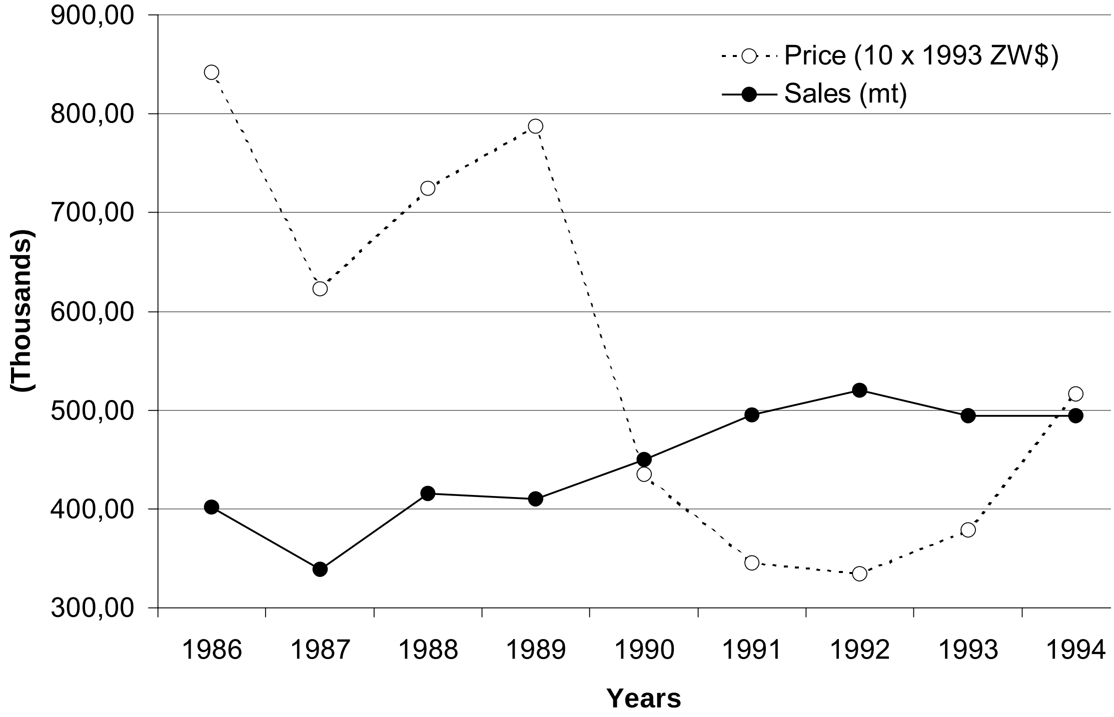
Figure 6-1: Insecticide sales and prices, 1986-1994.



Source: MUDIMU et al. (1995)

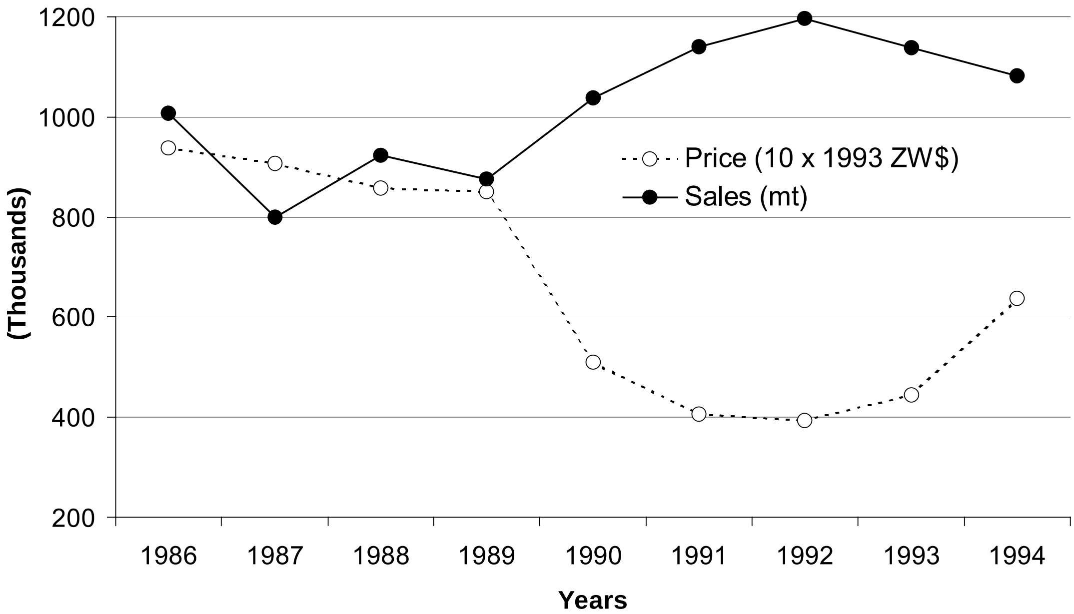
Figure 6-1 illustrates trends in insecticide sales and real prices between 1986 and 1994. After an initial deep in both sales and prices of pesticides between 1986 and 1987, prices and sales remained roughly constant up to 1989. In the 1989-90 agricultural season, real prices of pesticides dropped dramatically accompanied by increases in sales. This can be attributed to loosening of government controls and an increase in competition in the industry. This trend continued until 1991/92, a season when Zimbabwe experienced its worst drought ever. One can argue that the low sales after 1992 were due to cash flow difficulties experienced by farmers and also the shift in emphasis towards food crops by the majority of farmers. As will be discussed below, grain crops tend to be less pesticide demanding than export crops.

Figure 6-2: Fungicide sales and prices, 1986-1994.



Source: MUDIMU et al. (1995)

Figure 6-3: Herbicide sales and prices, 1986-1994.



Source: MUDIMU et al. (1995)

Figure 6-2 and 6-3 give similar pictures on the behavior of herbicides and fungicides as for insecticides. They tend to indicate a period of 1986 to 1989 when sales and prices tended to move in the same direction, and the period 1989 to 1994 when sales and prices move in opposite directions. The 1986-89 behavior reflects the cost plus pricing mechanisms used by industry and government, and the fixed negotiated quotas of chemicals which industry had to abide by. Thus supply and demand had little influence on pricing and sales. After 1989 there was a general decline in prices accompanied by increase in demand. Again this trend reversed in 1992, with sales declining and prices rising.

6.5 Cropping mix and demand for pesticides

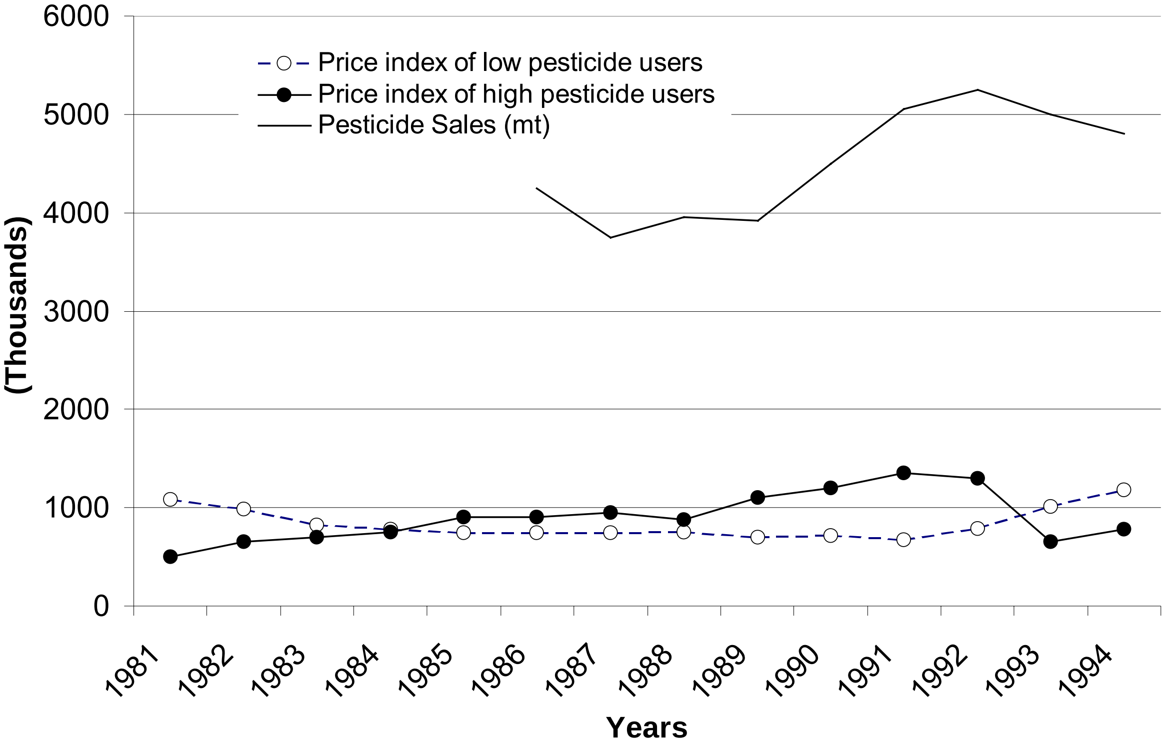
Different crops differ in their demand for pesticides. Table 6-5 ranks crops by their use of different pesticide on a per hectare basis based on the SZMEDRA (1994) study of 1993 pesticide use. The estimates show that the heaviest users of pesticides are tobacco, followed by coffee, vegetables, soybeans, and cotton. In the less pesticide demanding category were sugarcane, followed by wheat, barley, maize and groundnuts as the least demanding. According to the report of SZMEDRA (1994), communal farmers constitute 18% of the pesticide market compared to 82% in the commercial sector. This can partly be explained by their cropping mix being dominated by less pesticide demanding crops such as maize and groundnuts which together take up 82% of the cropped area compared to 36% in the commercial area. If we take an average of crop pesticide demands weighted by the proportion of land cropped to each for the communal and commercial sectors we estimate that the overall demand for pesticide per hectare of land is 0.47 and 4.41 kilograms in communal and commercial sectors, respectively.

Table 6-5: Crop pesticide usage in 1993 and demand in communal and commercial sectors

	Pesticide use (kg/ha) by crop				Proportion of land under crop	
Crop	**Fungicide**	**Insecticide**	**Herbicide**	**Total**	**Communal (%)**	**Commercial (%)**
Tobacco	0.62	15.06	1.19	16.86	0.3	19.1
Coffee	12.79	2.35	0.86	16.00	0.0	2.2
Vegetables	9.80	1.02	0.26	11.08	0.0	2.5
Soybeans		0.00	1.88	1.88	0.3	9.7
Cotton	0.03	0.78	0.36	1.17	17.0	12.2
Sugarcane	0.11	0.13	0.92	1.16	0.0	7.6
Wheat		0.09	0.38	0.47	0.0	8.1
Barley		0.14	0.16	0.30	0.0	1.3
Maize		0.05	0.24	0.28	67.6	35.2
Groundnuts	0.09	0.00	0.04	0.13	14.8	2.1
		Average use (kg/ha)			**0.47**	**4.41**

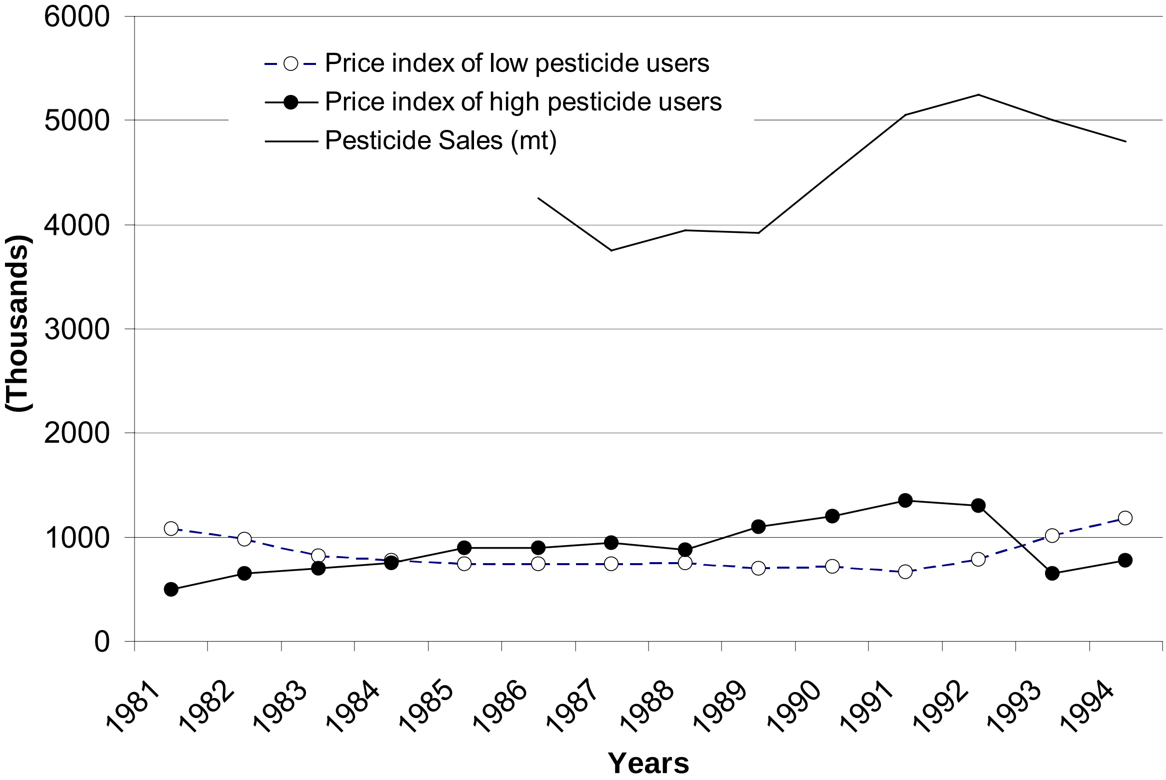
Source: MUDIMU et al. (1995)

Figure 6-4: Areas under high and low pesticide demanding crops.



Source: Based on CSO (various years)

Figure 6-5: Trends in producer prices (low vs. high pesticide demanders)



Source: Based on CSO (various years)

Taking the above line of reasoning further, one would expect increases in sales of pesticides to be related to increases in area put under pesticide demanding crops. Figure 6-4 plots sales and area cropped to pesticide intense and non-pesticide intense crops. From Figure 6-4, however, no clear-cut picture emerges about the relationship. What the graph does indicate though is a gradual decrease in area put under less pesticide demanding crops from 1986 to 1992 followed by an increase in area allocated to these between 1992 and 1994. Rather than observing an opposite trend in the case of high pesticide using crops, we observe wide swings in area allocated to these crops. Figure 6-5 gives a clearer correlation between differences in producer prices of less and high pesticide demanding crops and sales of pesticides. In 1980, prices of less pesticide demanding crops were relatively higher than those for high demanders. Since then and up until 1992, however, the terms of trade shifted in favor of the high demanders with the gap widening between 1989 and 1992. This coincided with a period of rises in pesticide sales. Since 1992 prices of less pesticide demanding crops have risen relative to high demanding crop prices. This has been accompanied by a drop in sales of pesticides.

6.6 Risk

In section 6.2 we identified essentially three hypotheses on interaction of risk and pesticide usage. The first was that a situation of high pest infestation uncertainty will result in high pesticide usage. The second hypothesis is that high yield uncertainty tends to encourage low pesticide use. Lastly, poverty tends to make farmers risk averse and is associated with farmers adopting safety first strategies in their choice of crops.

Available information does not permit us to make any meaningful deduction on the first hypothesis save to say that commercial farmers, because they crop large areas relative to communal, are more likely to be uncertain about degrees of infestations as compared to communal. Scouting a one hectare cotton crop for infestation is more likely to yield accurate measures of infestation than scouting a twenty hectare plot. Thus one would expect commercial farmers to apply more pesticides to guard against underestimation of infestation levels. Experience shows that this is the case in Zimbabwe agriculture.

Based on information on yields of major crops since 1980 (Ministry of Agriculture, 1997) we estimate the coefficient of variation of yields to be generally higher in communal than in commercial farming sectors. Alternatively, communal farmers face more yield uncertainty compared to commercial farmers. For communal and commercial sectors, respectively, coefficients of variation were estimated to be 46% and 26% for maize, 40% and 7% for cotton, 38% and 22% for soybeans, and 57% and 61% for groundnuts. These disparities can be attributed to commercial farmers being in better agroecological zones as well as having better access to irrigation. This evidence supports the low use of pesticides in communal compared to commercial.

The third hypothesis seems well supported by information on the Zimbabwe agricultural sector. The Ministry of Agriculture's Economics and Markets Branch's Annual Survey on eight communal areas farming (1989) shows that in 1988-89 season, 73.4% of land was allocated to grain crops, 6.7% to cotton, tobacco and soybeans and the rest split between groundnuts and sunflower. Of the eight communal areas in the survey, only four areas recorded appreciable levels of pesticide usage. These are areas in which soybeans, cotton, and/or tobacco were reported grown. Figure 6-4 also lends support to the food safety first argument. Following the severe drought of 1991/92 season maize, and hence low pesticide demanding crops, gained prominence as compared to cash crops.

6.7 Credit availability

One of the most limiting factors in the use of modern inputs in communal areas is lack of credit. This is a critical factor for pesticides which need capital investment in application equipment in addition to the cost of the chemical itself. The rise in chemical usage in this sector in the early eighties can be attributed to the parastatal Agricultural Finance Corporation (AFC) and the public company Cotton Company of Zimbabwe (Cotco) lending out input package loans. In the period 1986 to 1994, the general trend has been a decline in the number of AFC loans extended to the communal sector mainly due to reduction in government subsidies to the AFC, high cost of administering numerous small loans, high default rates, and lack of collateral. Table 6-6 chronicles the rapid decline in credit to this sector. In addition it also shows a decline in real terms of the value of loans to the communal sector which intensified from 1989. Since 1992 though, a recovery in value loaned has been noticed which ONI (1997) attributes to the group lending approach adopted by the AFC with the advent of the Economic Structural Adjustment Program (ESAP). This approach lowers the costs of screening and monitoring loan contract performance on the part of the lending institution and, because loans are to groups rather than single farmers, it also lowers administrative costs.

The exception to the above shortage of loans has been short term loans to cotton growers by the largest cotton buyer in Zimbabwe, Cotco. It is estimated that about 40% of cotton chemicals in the communal sector are sourced from Cotco (Chatwood, personal communication). The farmers would then repay their loans when they sell their harvest. However, the entrance into the market of other buyers, the largest being Cargill, has opened the possibility of farmers defaulting through diversion of sales to these alternative buyers.

Table 6-6: Loans extended to the communal sector by the AFC

Year	No. of loans to communal	Value of loans (1993 ZW$ million)
1986	77526	128.65
1987	77384	166.64
1988	69885	120.94
1989	57679	97.93
1990	43846	50.64
1991	30190	31.80
1992	27344	34.66
1993	15973	34.04
1994	13755	57.65

Source: AFC (various years)

The above credit constraints are mainly confined to the communal sector. The commercial farmers, because of their legal ownership of the land they farm, can use land as collateral to gain access to credit from both private and public financial institutions.

6.8 Conclusions

This paper discussed economic factors that have affected the level of use of pesticides in Zimbabwe agriculture. Specifically, the paper discusses the effects of price, risk, credit availability and cropping mix choices as factors affecting levels of pesticide use. Tentative estimates are also made of the degree of price responsiveness as well as inferences on the efficiency of use of pesticides in Zimbabwe.

The results of this study indicate that pesticide usage has been responsive to prices and the response has tended to be price inelastic. Through estimates of values of marginal product for insecticides, fungicides and herbicides, we can tentatively conclude that on the whole Zimbabwe has been an efficient user of pesticides.

This paper argues that the observed heavy use of pesticides in commercial relative to communal sectors can be attributed to a number of characteristics of these sectors. Commercial farmers have better access to credit, are in better agroecological regions, have better access to water and hence have lower yield risk; all properties associated with high pesticide availability or use. The advent of the ESAP in 1990 widened the gap in these characteristics between communal and commercial farmers.

This paper gave a broad overview of factors affecting pesticide use in Zimbabwe. Most factors affecting pesticide use, however, can only be assessed through farm level analysis of farmer decision making processes with regard to applications of pesticides.

References

AFC (various years): Annual report. Agricultural Finance Corporation, Harare.

Bunn, D.W. (1984): Applied Decision Analysis. McGraw-Hill Book Company, New York.

Chatwood (1995): (Chair of Agricultural Chemical Industry Association, personal communication).

Central Statistical Office (Various Years): Production account for agriculture, forestry and fisheries, government of Zimbabwe.

Lichtenberg, E. and D. Zilberman (1986): The econometrics of damage control - Why specification matters. American Journal of Agricultural Economics, Vol. 68, No. 2, pp. 261 - 273.

Ministry of Agriculture (1997): The agricultural sector of Zimbabwe: Statistical Bulletin: March 1997, Government of Zimbabwe.

Ministry of Agriculture (1989): The first annual report of farm management data for communal area farm units : 1988/89 Farming Season, Government of Zimbabwe.

Mudimu, D.G., S. Chugume and M. Chikanda (1995): Pesticide use and policies in Zimbabwe - Current perspectives and emerging issues for research. Pesticide Policy Project Publications No.2, University of Hannover, Germany.

Oni, S.A. (1997): Impact of ESAP on communal areas of Zimbabwe. Friedrich-Ebert-Stiftung, Harare.

Pannell, D.J. (1991): Pests and pesticides, risk and risk aversion. Agricultural Economics, Vol. 5, pp. 361 - 383.

Szmedra, P. (1994): Pesticides and the agricultural industry in Sub-Saharan Africa, environmental and natural resources policy and training (EPAT) project, Winrock International Environmental Alliance, Arlington, Virginia, USA.

7 Toxicology of Pesticides and the Occupational Hazards of Pesticide Use and Handling in Zimbabwe

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Abstract

Pesticides can be subdivided functionally into insecticides, herbicides, fungicides, fumigants, and rodenticides and others. The effectiveness of pesticides is based on their selective toxicity. However, the selective toxicity of these compounds is not full proof and as a result, toxic exposure to non-target organisms, including humans, is a common phenomenon, hence the problem of pesticide poisoning. Pesticide toxicity is described quantitatively through the use of dermal toxicity and the oral lethal dose, $LD_{50,}$ in conjunction with the colour coding system. Thus the toxicity of pesticides is correlated, in an incremental fashion to the colours green, amber, red and purple. This colour coding system, as used in Zimbabwe is borne out of a local experience and it is slightly different from the WHO/FAO internationally agreed approach. The recommended safe use or handling of pesticides is tailored to the different pesticide toxicity as based on the colour coding. A number of studies and surveys conducted to elucidate occupational hazards to use and or handling of pesticides indicate that toxic exposures from occupational encounters is very high in Zimbabwe. Over 50% of all farm workers in Zimbabwe are exposed to organophosphates during the spraying season. Provision and use of protective clothing among farm workers in Zimbabwe is minimal and together with poor knowledge of the health hazards of pesticides, contributes to the significant number of toxic exposures to pesticides in Zimbabwe.

7.1 Introduction

Toxicology in general terms is the study of harmful (injurious) effects of substances (chemicals) on living organisms and the ecosystem as a whole. Harm or injury covers a very broad spectrum of signs, symptoms and effects such as from a slight irritant itch to causing death. The degree of toxicity of a substance however depends on a number of factors, including the formulation of the substance, the dose of exposure, duration of exposure, age of victim, and health status of the victim, among other things. The toxicology of

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pesticides in particular is the study of the harmful effects of pesticides on non target organisms, such as humans and the ecosystem. Pesticides, (besides chemical agents used for warfare) are some of the only chemicals which are synthesised with the sole intention of causing death or harm to living organisms, be it pests though. As a result all pesticides possess some degree of toxicity harmful enough to most organisms. While it can be argued that pesticides possess selective toxicity it is, alas, unfortunately a reality that selective toxicity on target organisms is not as precise and discriminative as we would like it to be. Complete selectivity is something that has yet to be achieved although some recently introduced pesticides have very high degrees of selectivity, as a result toxic exposures from pesticides spills over to non target organisms. The main reason for this state of affairs is the fact that it is often very difficulty to differentiate some of the physiologic and biochemical systems of target organisms from those of the non-target organisms (ECOBICHON, 1991: 565). Consequently even as early as 20 years ago (COPPERSTONE, 1977) rough estimates of over 500,000 pesticide injuries were notified throughout the world. Four percent of these notified cases were deaths, i.e. 20,000.

Evaluating or determination of toxicity of chemicals or substances is based on a number of parameters. However, the most commonly used parameters of equating toxicity are the use of the LD_{50} and the use of the toxicity rating chart. The LD_{50} is the median oral lethal dose that kills 50% of the studied animal population (usually mice and/or rats).

The LD_{50} can be elaborated and translated so as to cover and explain the toxicity of a wide range of chemicals and different chemical formulations. One way of doing this is the use of the toxicity rating chart. This in fact is the use of the LD_{50} to rate chemicals numerically. At the same time, the numerical rating is correlated to the description of the degree of toxicity and to the formulation of the chemical (Table 7-1).

Table 7-1: Toxicity rating chart

Toxicity Rating	Description	LD_{50} single dose	Volumes
6	Extremely toxic	1 mg or less	less than 7 drops
5	Highly toxic	1-50 mg	7 drops to 5 ml
4	Moderately toxic	50-500 mg	5 ml to 30 ml
3	Slightly toxic	0.5-5 g	30 ml to 375 ml
2	Practically non toxic	5-15 g	375 ml to 750 ml
1	Relatively harmless	15 g or more	more than 750 ml

(a) The rating is based on mortality and not morbidity.

(b) It is based on acute toxicity of a single oral dose.

7.2 Toxicological classification of pesticides

Pesticides in particular are toxicologically graded by way of colour coding. However, before this stage is reached, pesticides have to be registered according to legislation. In Zimbabwe, this is done by the registering officer of the Plant Protection Research Institute, a department of the Ministry of Agriculture, in collaboration with the Hazardous Substances and Articles Control Board. Once registered the pesticide is assigned a colour code, i.e. green, amber, red or purple is assigned to a pesticide. The colour is based on the acute oral lethal dose, $LD_{50,}$ of the pesticide, the concentration of the formulation and the persistence of the pesticide in the ecosystem after application. The colours, green, amber, red and purple represent pesticides with LD_{50} ranges of > 2,001; 500 - 2,000; 101 - 500 and 0.1 - 100 mg/kg body weight respectively. Besides indicating the LD_{50} rating of a pesticide, the colour coding system also circumscribes the nature of the pesticides, in terms of what hazards the chemical possess, who, by law may handle or use it and the type of protective clothing that is required, by legislation, to be worn when one is handling or using the pesticide. For example, in Zimbabwe, the purple colour coded pesticides have an LD_{50} of 0.1 to 100 mg/kg body weight (the most toxic of pesticides), and are depicted by a purple triangle with the word ”danger ” and a symbol of a skull and cross bones appearing within the triangle and the words ”very dangerous poison” beneath the base of the triangle, may only be sold to persons whose business, profession or trade require them. These pesticides are sold only by licensed dealers who are obliged, by legislation, to keep a poison register of all sales. These pesticides should not be used by the general public since they are ”very dangerous poisons”. The red coded pesticides, which have an LD_{50} range of 101 - 500 mg/kg body weight are depicted by a red triangle with the word ”danger” and a symbol of a skull and cross bones appearing within the triangle and the words ”dangerous poison” beneath the base of the triangle. The conditions of use and handling of these pesticides are like wise specified. Similarly the amber coded pesticides, which have an LD_{50} of 501 - 2,000 mg/kg body weight are depicted by an amber triangle with the word ”danger” and a symbol of skull and cross bones appearing within the triangle and the word ”poison” beneath the base of the triangle.

The green coded pesticides have an LD_{50} of greater than 2,001 mg/kg body weight and are depicted by a green triangle with the word ”caution” within the triangle and the words ”harmful if swallowed” beneath the base of the triangle.

Pesticides are also classified toxicologically according to their chemical functions. This classification is composed of insecticides, herbicides, fungicides, fumigants and rodenticides. Annex 7-1 gives an account of the functional and chemical classification of pesticides and presents examples of the majority and most commonly used and encountered pesticides.

7.3 Toxicology of pesticides

Pesticide toxicology has been studied in appreciable depth and it is of concern to humans for a number of obvious reasons. Certain requirements have to be fulfilled before a pesticide is registered and acceptable for use. These requirements are based on the toxicity and safety aspects relating to use and or handling of the compound. The requirements include toxicity data regarding acute, subchronic, chronic, reproductive, carcinogenicity, mutagenicity and teratogenicity studies data. Furthermore establishment of tolerances for pesticide residues (e.g. acceptable daily intake, ADI and maximum residue limits MRLs), environmental impact, specifications of use and chemical nature of the pesticide are all important requirements, (ECOBICHON, 1991; 565). The risk and hazard from toxic pesticide exposure are associated with food contamination with pesticides during storage and or transportation, consumption of seed or food items which have been preserved with pesticides (seed preservatives), and had not been intended for eating, misuse or unsafe handling/application (occupational exposure), and misadventure, (suicides and parasuicides), MARRS, 1993; 1329). This is also true of the situation in Zimbabwe, (NHACHI and KASILO, 1996). The toxicology of the pesticides listed in Annex 7-1 is as diverse as the nature of these compounds. Insecticides perhaps possess the greatest hazard of toxic exposure to humans. These compounds are used in large amounts by a large number of people more frequently in the agriculture industry the world over. It is for this reason that there is more toxicological data available on insecticides than on the other pesticides.

7.3.1 Organochlorine insecticides

The organochlorine insecticides, though diverse in their chemical nature (they can be subdivided into three groups, Annex 7-1) share a number of important properties which have a toxicological bearing. They persist in the ecosystem (they are not easily biodegradable), they accumulate (bioconcentration) in the environment and in the food chains which results in biomagnification. In general toxic doses of these insecticides interfere with transmission of nerve impulses. This disruption in nerve impulse conduction interferes with brain function in behavioural changes, involuntary muscle activity and depression of respiration. Irritability of the myocardium can cause arrhythmias, induction of liver enzymes and production of lesions and degenerative changes in the liver. However the acute signs and symptoms of organochlorine insecticides include apprehension, excitability, headache, dizziness, perithecium muscle twitching tonic and clonic convulsions and in high doses coma may result, (ILO, 1979: 108).

Because DDT (dichlorodiphenyl trichloroethane) is the most studied of the organochlorine insecticides, the mechanisms of toxicity of these insecticides are based on those of DDT. Thus the interference of impulse conduction by OCs, can be explained by the fact that DDT acts through at least four mechanism, i.e. reduces potassium transport across membranes; it alters the pores of the sodium channels and this interferes with the active transport of sodium out of the nerve axon during repolarisation. DDT inhibits neuronal adenosine triphosphate (ATPase), especially the Na^+, K^+, ATPase and Ca^{2+} - ATPase. It also inhibits the transportation of calcium ions. The overall consequent is an increased sensitivity of the neurons, (ECOBICHON, 1991; 573). DDT has a toxicity rating of 4 (i.e. very toxic) with an LD_{50} of 0.5 to 5 grammes per kilogramme body weight. The cyclodienes and cyclohexane type of organochlorine insecticides exert their toxicity through a different mechanism to that of the DDT type. The common symptom of toxic exposure to these compounds is central nervous system ((CNS) stimulation. They achieve this by antagonising y-aminobutyric acid (GABA), a neurotransmitter in the CNS. This action is identical to that of picrotoxin, a CNS stimulant. These insecticides also inhibit the enzymes Na^+, K^+ - ATPase and Ca^{2+} , Mg^{2+} - ATPase, resulting in induction of stimuli propagation in the CNS.

Poisoning due to organochlorines is treated symptomatically and in the presence of convulsion, diazepam is the recommended anticonvulsant except in the case of endosulfan poisoning.

7.3.2 Organophosphate and carbamate insecicides

Of the insecticides, the cholinesterase-inhibiting organophosphates and carbamates are associated with most of the toxic pesticide exposures because of their wide and frequent usage. Symptomatically the toxic effects of organophosphates can be divided into the parasympathetic, sympathetic, CNS and neuromuscular junction effects. The signs and symptoms of parasympathetic effects include salivation, constriction of the pupil of the eye and abdominal colic; the sympathetic effects cause restlessness, mental confusion, loss of memory, convulsions and coma and lastly the neuromuscular junction effects cause muscle fasciculation and paralysis. The immediate cause of death due to poisoning by organophosphates and carabamates, (i.e. the terminal effect) is as a result of respiratory paralysis. The mechanisms of toxicity due to organophosphates and carbamates is similar. These compounds inhibit the enzyme acetylcholinesterase. The result is an accumulation of acetylcholine at nerve-end plates causing the clinical pictures discussed above. Treatment is by administering atropine, to block the effects of acetylcholine.

Some organophosphates (phosphoroamidates and phosporates), cause organophosphate-induced delayed neuropathy, (OPIDN). This usually occurs 7 to 14 days after exposure. The lesion that occurs is a sensory-motor axonopathy, resulting in inhibition of nerve membrane transmission. Symptomatically this results in paralysis of the limbs, especially the lower limbs. OPIDN is age dependent, with children being less resistant, (GOLDSTEIN, 1988; 179). The main differences between organophosphates and carbamates are that the effects of carbamates are reversible and also carbamates are not associated with induction of delayed neuropathy. The toxicity ratings of organophosphates and carbamates are very varied, for instance, parathion has a toxicity rating of 6 (super toxic) and malathion 5 (highly toxic) and carbary, 4 (very toxic).

7.3.3 Pyrethroid / Pyrethrin insecticides

The pyrethoids/pyrethrins are relatively recently introduced pesticides, especially in the Zimbabwe context. Pyrethrins are naturally occurring and are based on the pyrethrum plant. The pyrethoids are the synthetic analogues. Occupational exposure is associated with burning, itching and/or tingling sensation of the skin. This is usually made worse by applying warm water or sweating. These symptoms usually do not last for more than 24 hours. Ingestion of the compounds is associated with anorexia, paraesthesia, palpitations and tightness in the chest among other things. Some pyrethroids act as allergens and incidence of allergic rhinitis and or asthma are common. There is evidence that these pyrethroids are neurotoxic. Treatment of toxic exposures is non specific i.e. symptomatic and supportive treatment are recommended (ECOBICHON, 1991).

7.3.4 Bipiridillium herbicides

The bipiridillium herbicides are very toxic compounds with toxicity ratings of 4 to 5 (very toxic to highly toxic for paraquat) and 4 for deiquat. Paraquat is the most widely studied of the two and presence with characteristic and specific lesions. While paraquat is selectively toxic to the lungs, ingestion initially produces damage to the gastrointestinal tract (GIT), symptomised by pain, vomiting and diarrhoea. This happens after about 24 hours. In the next 48 to 72 hours their evidence of kidney damage (an increase in serum enzymes (GOT, GPT) activity, alkaline phosphate activity). Finally after 72 to 96 hours, injury to the lungs is evidenced by diffused pneumonitis and intra-alveolar oedema and or respiratory failure, (HIGENBATTAM et al., 1979: 161, SCHUSTER et al., 1981). Paraquat is selectively concentrated in lung tissue. It is then converted into free radicles which react with oxygen to form hydrogen peroxide and superoxide anions. These attack cell membranes causing damage to lung tissue membranes. One of the main hazards of paraquat exposure is that toxic doses in people vary widely and as such any ingestion event ought to be treated urgently. There is usually no lung effects with deiquat but kidney injury is more severe. Treatment for paraquat-induced lung injury is not available. The probable effective step to take is to prevent absorption from the GIT.

The use of 2,4,5-T, a phenoxy herbicide is not that common anymore. This is due to fear of contamination with TCCD (2,3,7,8-tetrachlorodibenzo-p-dioxin during synthesis. TCCD is carcinogenic. On the other hand its analogue, 2,4-D is a popular herbicide, used against broad leaved weeds. 2,4-D is moderately toxic, with a toxicity rating of 3 to 4, and toxic hazards are associated with very large doses. Some of the symptoms associated with toxic exposure are alternations in consciousness, vomiting and convulsions.

7.3.5 Fungicides

Among the fungicides, the organometals are very toxic. For instance ethyl mercuric chloride has a toxicity rating of 5 to 6 and organotins such as tributyltin are known neurotoxins and tributyltin is immuntoxic. As a result the use of these fungicides is restricted (Advisory Committee on Pesticides, 1990; IPCS, 1990).

The phenol fungicides such as pentachlorophenol are widely used wood preservatives. Pentachlorophenol has a toxicity rating of 4 and risk of poisoning is associated with ingestion, which is not a common event. If ingested, it causes hyperthermia (fever). This is because pentachlorophenol uncouples oxidative phosphorylation and thus chemical energy is dissipated as heat energy.

The dithiocarbamates (EBDC compound) are associated with very low toxicity in acute exposure and incidence of acute toxic exposure are rare. However, these fungicides are not commonly used because of an indirect association with teratogenic, mutagenic and carcinogenic effects in some animal studies. This is because the EBDC compounds are biodegraded to ethylene thiourea (ETU), a known potent mutagen, teratogen and carcinogen.

7.3.6 Gaseous fumigants

The gaseous fumigants such as hydrogen cyanide, carbon disulphide and phosphine are very toxic substances. This is because they are volatile and are rapidly absorbed and interfere with chemical respiration in cells throughout he body. Some of the symptoms of toxic exposure to these gases are shortness of breath, pulmonary irritation, nausea, headache and jaundice. The small molecular halogenated hydrocarbons such as methyl bromide, ethylene dichloride and dichloropropene depress the CNS and cause injury to the liver, (hepatotoxic). There is evidence that ethylene dibromide, when inhaled causes pulmonary oedema. Fatality is associated with ingestion of amounts of not less than 5 mls.

Naphthalene, sulphuryl fluoride and parachlorobenzene are moderately toxic fumigants, with LD_{50}'s of between 0.5 and 5 mg/kg body weight, i.e. toxicity rating number of 3. When ingested naphthalene can however cause haemolysis which may lead on to tubular necrosis. Parachlorobenzene is associated with sensitisation in some individuals. Sulphuryl fluoride induces CNS depression. Management of fumigants poisoning is also symptomatic with emphasis on maintaining respiration by administering oxygen if necessary until hospitalisation.

7.3.7 Rodenticides

The majority of rodenticides are added to baits that are not meant for human consumption. This reduces the hazard of toxic exposures to humans. However ingestion of rodenticides accidentally or intentionally constitutes an emergency because of the high doses which are usually incorporated in these formulations, the severity of the symptoms, the distress they cause and the fact that more often than not the victims of accidental ingestion are children who are easily overwhelmed by these toxins due to the small body weight to dose relationship. Due to the high hazard-outrage impact, toxic exposure by rodenticides, their toxicology has been studied extensively, (HAYES, 1982). One of the cheapest and effective rodenticides is Zinc phosphide. For these reasons, it is extensively used in poorer societies, (less developed nations). Intoxication causes vomiting, diarrhoea, tachycardia , fever and restlessness among other symptoms. These effects are due to phosphine which is released in the GIT after hydrolysis of zinc phosphide.

Fluoroacetic acid and its derivatives, such as fluoroacetamide are highly toxic compounds because they inhibit cellular respiration (i.e. they interfere with the tricarboxycylic acid cycle processes) through a mechanism of lethal synthesis. Fluoroacetic acid has an LD_{50} of less than 5 mg/kg, i.e. it is super toxic. Because of this extreme toxicity the use of this class of rodenticides is restricted. The signs and symptoms of toxicity after ingestion include nausea, vomiting, sinus and vetricular tachycardias, hypotension, urine retention, agitation and comma. Management of toxicity is symptomatic and non specific. On the other hand a rodenticide like *x*-Naphtyl Thiourea, (ANTU), is almost non toxic to human beings but very toxic to rodents. It is a fairly non hazardous compound to humans. Pyrinimil which is also a substituted urea compound is however toxic to human beings. Pyrinimil, N-(3-pyridinylmethyl)-N^1-(4-nitrophenyl) urea, toxic exposure is associated with orthostatic hypotension, polyuria, polydipsia, dyspnea and necrologic impairment, (LE WITT, 1980).

Perhaps the most commonly known rodenticides are the anticoagulants. Warfarin, [3-(*x*-acetonylbenzyl)-4-hydroxy-coumarin] acts by antagonising the actions of Vitamin K. It thus inhibits the hepatic synthesis of prothrombin (factor II) and the other clotting factors VII, IX and X. Anitcoagulation takes 8 to 12 hours after ingestion. The 8 to 12 hours period is the approximate turn-over time of the clotting factors, (KATONA and WASON, 1986). Warfarin does not pose high hazard since it takes multiple or repeated doses for toxicity to ensure. Unfortunately rodents quickly acquire resistance. This prompted the development of analogues, such as brodifacoum and diphacinone, and indanedione which in fact is a different class of chemicals from the warfarin class. These latter anticoagulants have been effective so far. Once more toxic exposures to humans are rare and accidental whenever they occur, (HAYES, 1982; JONES et al. 1984; LIPTON and KLASS, 1984). In these cases of accidental ingestion or parasuicides, bleeding of the gums and nose bleeds are usually the first symptoms. This may be accompanied by advent of haematomas around the knee and elbow joints. The signs and symptoms can persist for a long time after termination of exposure, especially with the new generation coumarins.

7.4 Empirical data from Zimbabwe

A number of studies, regarding the occupational hazards of pesticide use and or handling have been carried out in Zimbabwe. In a study on the epidemiology of the health impact of pesticide use in Zimbabwe it was shown that about 50% of workers on large scale farms involved in pesticide use in Zimbabwe are exposed to organophosphates during the spraying season, January to March (LOEWENSON and NHACHI, 1996). This study involved repeated cross-sectional surveys of occupational exposure to organophosphates as assessed by comparing cholinesterase activity in sprayers and non sprayers before, during and after the spraying season. The study covered 3 of Zimbabwe's 9 provinces and these are the main cotton/coffee growing areas. The study estimated that about 10 000 workers are exposed to organophosphates in this occupational category alone.

This field survey study further indicated that pesticide exposure is associated with use of manual spraying techniques, low levels of provision of protective clothing and inadequate dissemination of safety information to workers. Also it seems that spraying technologies judged "safe" when new from the factory became a source of exposure when poorly maintained and incorrectly used.

Another survey, was done in pesticide manufacturing factories. The survey covered 4 factories in Harare, which together formulate and package 90% of organophosphates used in the country. In each of the factories, the study involved a general factory inspection (a walk-through survey) with interview of management, administration or an open-ended questionnaire and estimation of blood cholinesterase activity. The results of the cholinesterase activity were matched against the questionnaire results. The results of the survey revealed that there is excessive exposure to organophosphates at the workplace. The study recommended that preventive measures such as prohibiting smoking at the workplace, improvement in personal hygiene and basic worker education programmes be introduced to significantly reduce the prevalence of organophosphate pesticide exposure at the workplace (MATCHABA, 1996). This study was done in all but one of the factories which are involved in the manufacture and or packaging of pesticides in Zimbabwe.

In yet another study, on occupational exposure to DDT among the vector control workers, it was pointed out that up to 49% of the spraymen show evidence of toxic exposure to DDT as evidenced by high levels of DDT and its metabolite DDE in the spraymen's plasma, (NHACHI et al., 1996). Once more smoking seem to predispose workers to toxic exposures. Also, inadequate provision of protective clothing or improper use or/and lack of use of protective clothing, exasberts toxic exposure. In this study, DDT spraymen were screened of plasma vitamin A and DDE levels during the DDT spraying period

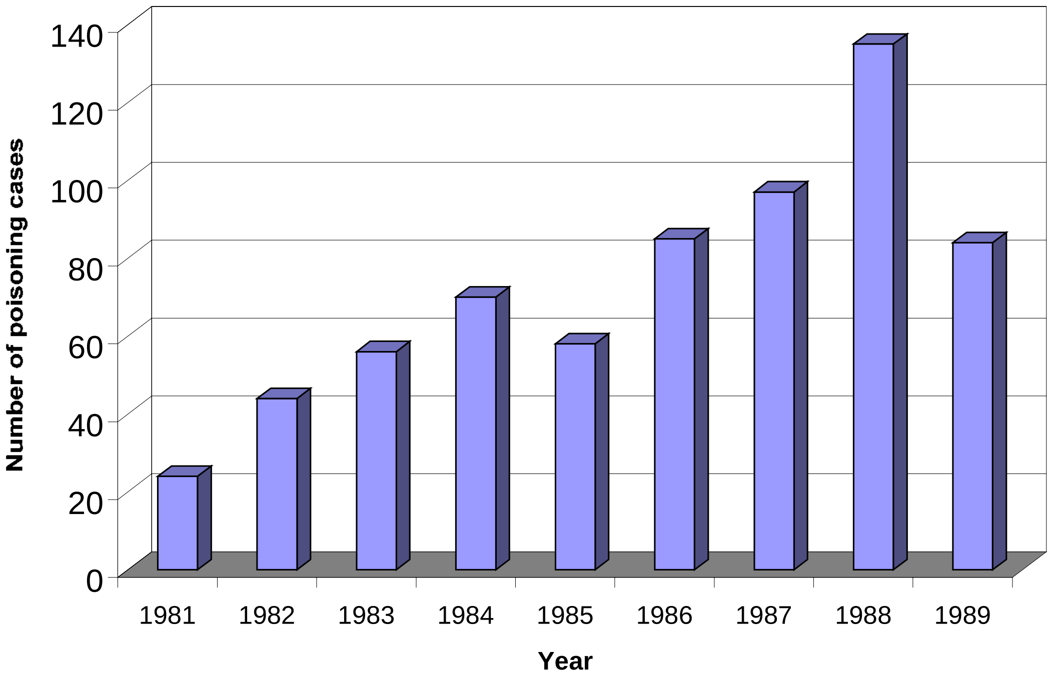
(September to March of 1988, 1989 and 1990). Spraying is done using ultra-low volume (ULV) dispensers which are strapped on the backs of the men.

Organophosphate poisoning in urban Zimbabwe was studied in a retrospective survey of the six main urban centres in Zimbabwe over the period 1980 to 1989, inclusive. The study showed an increase in poisoning events, from 1980 to 1989, see Figure 7-1 (KASILO et al., 1991). This finding is related to the fact that there has been an increase in usage of pesticides which is correlated to an increased acreage under cultivation, (LOEWENSON and NHACHI, 1996). It is fairly reasonable therefore to suggest that this increase in events of poisoning is related to occupational exposures. It is also possible that there has been an increase and better recording of poisoning cases at hospitals and this would suggest that there has always been a high prevalence of pesticide poisonings. The same study showed clearly that the age group most prone to toxic exposure is the 15 to 40 year age group, (Figure 7-2). Again this is logical and in agreement with the trend, i.e. the 15 to 40 year age group lies within the working age group. Insecticides were the fifth most prevalent chemicals associate with poisoning events in a study on the pattern of poisoning in urban Zimbabwe, see Figure 7-3, (NHACHI and KASILO, 1992: 435). It should be pointed out that a seasonal distribution of poisoning cases is not apparent in the long term data and this is due to the fact that the long-term data were based on only urban studies, which are dominated by accidental, suicidal and parasuicidal episodes, and these are not seasonal.

Legislation prescribes the recommended procedures of use and or handling of pesticides, so as to reduce toxic exposure events. It is recommended that when handling or using green labelled pesticides, long sleeved overalls should be worn when spraying or applying the pesticides, and rubber gloves should be worn mixing the pesticide. When handling amber coded pesticides, it is recommended that long sleeved overalls be worn, including rubber boots and gloves when mixing and face shield when spraying. Handling of the red colour coded pesticides should be restricted to horticultural, agricultural and industrial pest control. They may only be applied in the home by a registered recognised pest control operator and only sold by a licensed dealer. Protective clothing recommended for this class of pesticide include long sleeved overalls, rubber boots and gloves, face shield when mixing and spraying.

Purple colour coded pesticides, the most toxic, may only be sold to persons whose business, profession or trade require them. They may only be sold by licensed dealers who must keep a poison register of all sales. These should not be used by the general public. The recommended protective clothing include water-proof jacket and trousers, rubber boots and gloves, face shield or hood and a respirator in some cases (MUCHENA, 1996).

Figure 7-1: Distribution of poisoning cases according to year



The data for the 1989 period is from January 1 to August 31 1989

Figure 7-2: Distribution of poisoning cases according to age

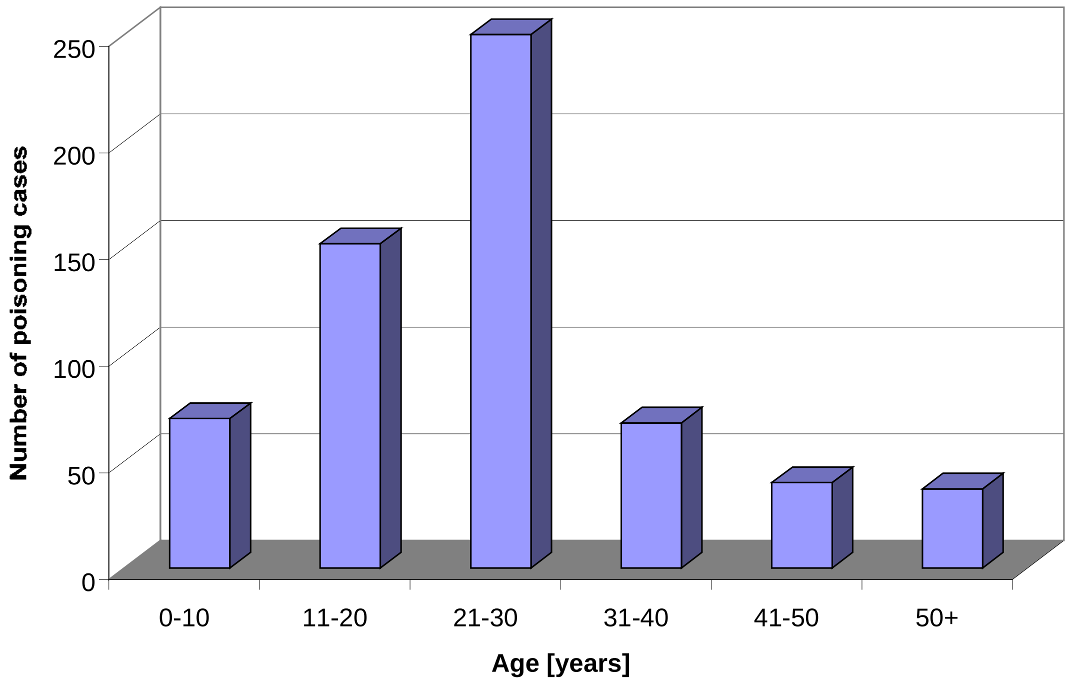
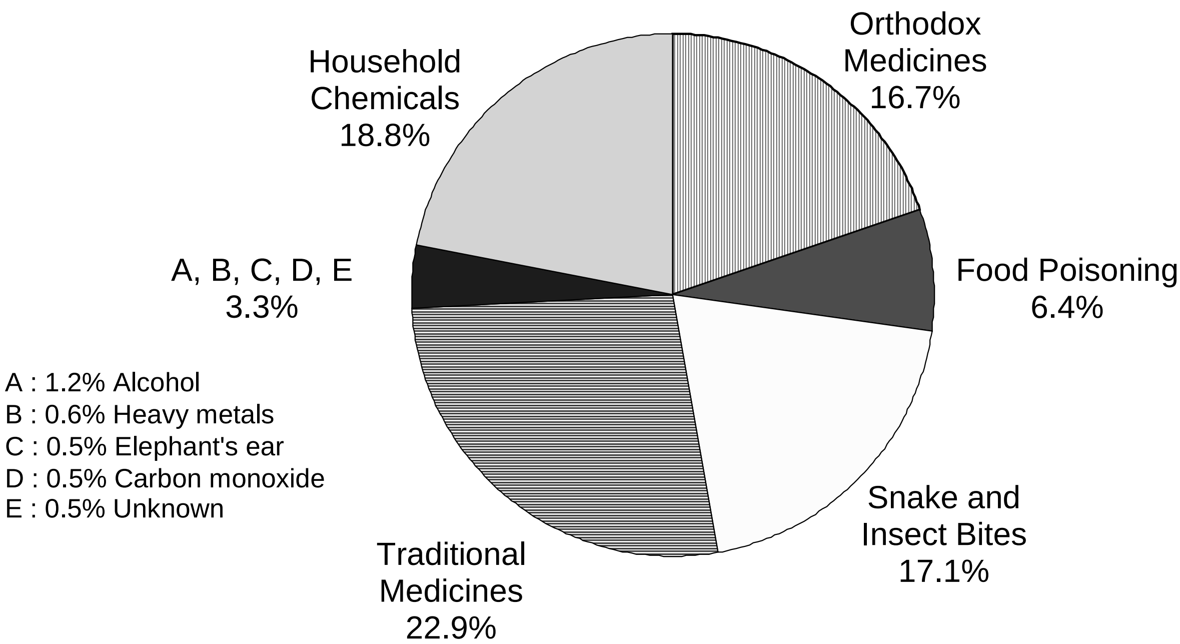


Figure 7-3: Spatial distribution of the chemical associated with poisoning



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References

Advisory Committee on Pesticides (1990): Annual Report, 1989. London, Edinburgh and Belfast: HMSO.

Copplestone, J.F. (1977): A global view of pesticide safety. In: D. Watson and W.W. Brown (eds): Pesticide management and pesticide resistance, p 147-158. New York: Academic Press.

Ecobichon, D.J. (1991): Toxic effects of pesticides. In: M.O. Admur, J. Doull and C.D. Klaassen (eds.): Casarett and Doull's Toxicology, The basic science of poisons, 4th Edn. New York et al.: McGraw-Hill, Pergaamon Press. pp. 565 - 622.

Goldstein, D., McGwigan and Ripley B.D. (1988): Acute trionesyclphosphate intoxication in Childhood. Human Toxicology, Vol. 7, pp. 179.

Hayes, W.J. (ed., 1982): Pesticides studied in Man. Baltimore: Williams and Williams.

Higenbottam, T., P. Crone, D. Parkinson and J. Nunn (1979): Further clinical observations on the pulmonary effects of paraquat ingestion. Thorax, Vol. 34, pp. 161 - 165.

International Labour Office (ILO) (1979): Guide to health and hygiene in agricultural work. Geneva.

IPCS (1990): International Programme on Chemical Safety. Environmental health criteria 116. Tributyltin, compounds. World Health Organisation, Geneva.

Jones, E.C.O., G.H. Growe and S.C. Naiman (1984): Prolonged anticoagulation in rat poisoning. Journal of American Medical Association, Vol. 252, pp. 3005-3007.

Kasilo, O.M.J., T. Hobane and C.F.B. Nhachi (1991): Organophosphate poisoning in urban Zimbabwe. Journal of Applied Toxicology, Vol. 11, pp. 269 - 272.

Katona, B., and S. Wason (1986): Anticoagulant rodenticides. Clinical Toxicology Review, Vol. 8, pp. 1 - 2.

Lewitt, P.A. (1980): The neurotoxicity of the rat poison vacor, A clinical study of 12 cases. New England Journal of Medicine, Vol. 302, pp. 73 - 77.

Lipton, R.A. and E.M. Klass (1984): Human ingestion of a 'superwarfarin' rodenticide resulting in prolonged anticoagulant effect. Journal of the American Medical Association, Vol. 252, pp. 3004-3005.

Loewenson, R. and C.F.B. Nhachi (1996): Epidemiology of the health impact of pesticide use in Zimbabwe. In: C.F.B. Nhachi and O.M.J. Kasilo (eds.): Pesticides in Zimbabwe - toxicity and health implications, University of Zimbabwe Publications, Harare. pp. 25-37.

Marrs, T.C. (1993): Toxicology of pesticides. In: B. Ballantyne (ed.): General and applied toxicology, Vol. 2. New York: Stockton Press, Basingtoke: Macmillan Press. pp. 1329 - 1342.

Matchaba, R.B.Z. (1996): Organophosphate exposure in pesticide formulating and packaging factories in Zimbabwe. In: C.F.B. Nhachi and O.M.J. Kasilo (eds.): Pesticides in Zimbabwe - Toxicity and health implications. University of Zimbabwe Publications, Harare. pp. 51-62.

Muchena, P. (1996): Legislation and registration of pesticides used in plant protection in Zimbabwe. In: C.F.B. Nhachi and O.M.J. Kasilo (eds.): Pesticides in Zimbabwe - toxicity and health implications. University of Zimbabwe Publications, Harare. pp. 1-11.

Nhachi, C.F.B., and O.M.J Kasilo, (1992): The pattern of poisoning in urban Zimbabwe. Journal of Applied Toxicology, Vol. 12, pp. 435-438.

Nhachi, C.F.B., W. Murambiwa, R. Urombo and O.M.J. Kasilo (1996): Occupational exposure to DDT among the mosquito control sprayers in Zimbabwe. In: C.F.B. Nhachi and O.M.J. Kasilo (eds.): Pesticides in Zimbabwe - Toxicity and health implications. University of Zimbabwe Publications, Harare. pp. 80-88.

Nhachi, C.F.B. and O.M.J.Kasilo (1996): Pesticides in Zimbabwe, toxicity and health implications. University of Zimbabwe Publications, Harare. p. 115.

Schuster, R., I. Erlelenz and H.J. Von Romatouski (1981): Frühbild der Lungenfibrose nach Zytostotika and Paraquatintoxikation. Röntgenblätter, Vol. 34, pp. 338-341.

Annex 7-1: Classification of pesticides

Functional Classification	Chemical classification	Examples
INSECTICIDES	ORGANOCHLORINE	
	(i) Dichlorodiphenylethanes	DDT, Methoxychlor, Kelthane, Chlorbenzylate
	(ii) Hexachlorocyclohexane	Lindane, Benzene hexachloride
	(iii) Cyclodienes	Endrin, Aldrin, Dieldrin, Chlordane, Toxaphene, Endosulfan
	ANTICHOLINESTERASES	
	(i) Organophosphates	Malathion, Parathion, Monocrotophos, Mevinphos, Dichlorvos, Dioxathion, Diazinon, Dimethoate, Chlorpyriphos, Fenitrothion, Triazophos
	(ii) Carbamates	Carbamyl, Carbofuran, Aldicarb, Propoxur, Metalkamate, Dimetilan, Methiocarb, Oxamyl
	PYRETHRINS / PYRETHROIDS	Deltamethrin, Permethrin, Allethrin, Fluvalinate, Fenvalerate, Cypermethrin, Phenothrin, Tetramethrin, Kedathrin
	BIOLOGICALS	Abamectin, Rotenone, Nicotine
	HORMONE ANALOGUES	Hydroprene, Methoprene
	CHITIN INHIBITORS	Diflubenzuron
HERBICIDES	BIPYRIDYL DERIVATIVES	Paraquat, Deiquat, Morfoxone
	CHLOROPHENOXY/ COMPOUNDS	2,4-dichloro-phenoxy acetic acid (2,4-D), 2,4,5-trichlorophenoxy acetic acid (2,4,5-T), 4-chloro-otoloxyacetic acid, (MCPA).
	OPHEBICIDES	Glycophosate [N-(phosphorno-methyl) glycine] 5,5,5-tributyl-phosphorotrithioate (DEF), 5,5,5-tributyl-phosphorotrithioate (merphos)
FUNGICIDES	ORGANOMETALS	Organomercurials e.g. methy and methoxy-ethylmercuric chloride; organotins e.g. tributylin oxide
	PHENOLS	Pentachlorophenol, Dinitrophenol
	HEXACHLOROBENZENE	Hexachlorobenzene
	DITHIOCARBAMATES	Dimethyl-Bisdithio-carbamate; ethylene-bisdithiocarbamate (EBOC)
	PHTHALIMIDES	Folpet, Captafol

Functional classification	Chemical classification	Examples
	CARBAMATE FUNGICIDES AND THIABENDAZOLE	Benzimidazole derivates e.g. benomyl and bendazine, thiabendazole
FUMIGANTS	GAS FUMIGANTS	
	(Enzyme toxins)	Phosphine, Hydrogen cyanide, Carbon disulphide, Acrylonitide
	LIQUID FUMIGANTS	
	(Hydrogenated hydrocarbons)	Methyl bromide, Ethylene dibromide, Ethylene dichloride, Carbon tetrachloride, Dichloropropene, Chloropicrin
	MISCELLANEOUS FUMIGANTS	Sulphuryl fluoride, Paradichlorobenzene, Naphthalene
RODENTICIDES		Zinc phosphide*x*-Naphtyl thiourea (ANTU)
	SUBSTITUTED UREA COMPOUNDS	N-(3-pyridinylnethyl)- N-(4-nitrophenyl) urea
	FLUOROACETIC ACID & DERIVATES	Sodium fluoroacetate, Fluoroacetamide
	ANTICOAGULANTS	
	(i) Coumarin type	Warfarin, Coumafunyl
	(ii) 1,3-Indandione type	Diphacinone, Chlorophacinon, Pindone
	NORBARMIDE	Norbormide

8 Pesticides and the Ecosystem

Chris H.D. Magadza[1]

Abstract

The paper reviews the ecological impacts of pesticide application in Zimbabwe, especially with reference to the use of DDT in tsetse fly and malarial mosquito control. The evidence indicates landscapes level of environmental contamination, both in the terrestrial and aquatic environments. The presence of the pesticides was also detectable in areas where no pesticide had been applied, indicating a transfer mechanism possibly by volatilisation an precipitation, or wind borne aerosol transport during field application or both. Soil microbial respiration in treated areas was depressed while soil epigeal fauna showed species composition differences detectable over a period of several seasons. There was measurable population decline in the test reptile, *Mabuya striata*, indicating possible impacts among other reptiles. Crocodile eggs *(Crocodilus niloticus)* from the sprayed area are known to have considerable levels of DDT products. Several bird species, particularly insectivorous and raptorial species showed significant population declines associated with the pest control programme. One species showed an 88% population decline 33 months after cessation of application of the pesticide. Egg thinning was observed in a number of raptor species. Among the terrestrial vertebrates the data indicated increased mortalities as well as possible loss of probably as many as twenty bat species in the sprayed area. There was observed reproductive failure in *Eptescius hidebrandtii* due to DDT poisoning of the pups by lactating females. The paper further notes the accumulation of the pesticides among the fish species and suggests some applications, such as in crop production no detailed studies have been done to evaluate the ecological impacts of pesticide application and that the impacts could be significant and chronic. It cites the disappearance of *Boophagus africanus and B. erythrorhyncus* from cattle ranching areas. The paper concludes with a discussion on criteria for judging ecological impacts of pesticides as being significant, and recommends that rather than consider the so called ”landscape effects” of mass mortalities and large scale species loss, the evidence shown in the study of population stress, reproductive impairment

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and cumulation of the pesticide in the ecosystem should be sufficient evidence of significant impacts.

8.1 Introduction

In central southern Africa the tsetse fly, *Glossina morsitans* and *G. pallidipes* group formerly occupied most of the savanna woodlands. The fly populations were most dense in low lying terrain, below 1000 m above sea level. The tsetse are host species to protozoan blood parasites of the *Trypanosoma* genus, notably *T. congolense*, and *T. rhodesiensis*. These are pathogens for livestock diseases and the human sleeping sickness.

Following the construction of Kariba dam in the Zambezi valley resettling the Tonga was necessary, and later, other land hungry peasant populations. To enable the settlers to keep livestock, and to protect them from the sleeping sickness disease, it was necessary to clear the settlement areas of the tsetse fly.

Fly control methods have consisted of a mixture of ecological and chemical methods. Ecological methods consisted of destruction of the perceived fly habitat (clearing of riverine vegetation and thickets), and denying the fly its food source (eradication of wildlife vertebrate populations). The chemical methods included the use of chlorinated hydrocarbons, such as DDT, Dieldrin, Aldrin and Endosulfan. Except Endosulfan, which was administered as a topical ultra-low volume aerosol, all other chemicals were applied as persistent residual pesticide, the effects of which lasted up to six months after application.

Besides the Zambezi valley, DDT has been extensively applied in other low lying tsetse infested areas of Zimbabwe, particularly the Gonorezhou area. Here scars of tsetse control activities are still evident as non-vegetated areas originally cleared by earth moving machinery to clear fly habitats.

In the period between 1978 and 1989, DDT application for tsetse control in Zimbabwe has averaged 200 tones per year, peaking to 443 tonnes in 1986 (DOUTHWAITE and TINGLE, 1995). Total usage up to 1989 is estimated at some 3,837 tonnes. In the period 1968 to 1979 a total of 36,625 km^2 were treated with the insecticide, while the period between 1979 and 1990 saw another 32,550 km^2 treated. The frequency of application in the treated areas varied with the intensity of infestation. The most heavily treated area is the Zambezi valley, where some areas have been sprayed as much as 13 times.

Besides use of DDT in tsetse fly control this pesticide is also extensively used in Malaria control. In this usage the pesticide is applied inside human dwellings in the affected area, and on potential mosquito breeding places. Because of the belief among operators that DDT has no harmful effects on human health the insecticide is liberally applied. This results in householders having to sweep out considerable amounts per hut of excess pesticide which is then disposed of on the homestead. The total usage of DDT in this sector grew from ten tonnes in 1980 to 300 tones in 1990 (BLAIR RESEARCH INSTITUTE, 1990). At the peak of the control program all rural areas below 1200 metres above sea level were sprayed “regardless of prevailing epidemiological or entomological status” (BLAIR RESEARCH INSTITUTE, 1990).

More recently acetone odour baited traps have been developed in conjunction with chemosterilant. The baits are deployed in fly infested areas. The attracted flies come into contact with chemosterilant treated surfaces and fly off sterile. In this method no pesticides are applied to the environment.

The first environmental impact assessment of tsetse control was done during the first large-scale aerial application of Endosulfan in the Western province of Zambia by MAGADZA (1978). He also published some data on the toxicity of Endosulfan to some aquatic organisms commonly found in the area (MAGADZA, 1983).

DDT is a broad spectrum pesticide applied mainly to insect pests. It affects the neuro-motor system of the animals, resulting in death. It is a topical pesticide that need only to come into contact with its target animal to cause death.

In its early usage DDT appeared to have few effects on large mammals, a misconception still sometimes promulgated by DDT promoters in developing countries. During its extensive use it became apparent that the pesticide was toxic to some vertebrates, and has been associated with damage to the brain, leading to death (ANJUM et al., 1990).

Next came the discovery that DDT caused the thinning of egg shells in birds of prey, causing reproductive failure. This effect was also later found in other birds, such as the mallard duck. More recently however it has been established that DDT and related compounds have a wide range of toxicological effects. These include biochemical enzyme interference (MISKIEWICZ et al. 1992) and hormonal abnormalities (including gender changes, RALOFF 1994, 1995a) in many vertebrate animals. Among humans MCEWEN and STEPHENSON (1979) noted that chronic effects of sublethal doses of DDT included interference with thyroid activity resulting in disturbance of steroid hormones metabolism. Similar effects on thyroids of birds have been recorded by JEFFERIES and FRENCH (1971, cited in MORIARTY 1983), where thyroid hyperplasia was implicated in egg shell thinning through impairment of the Ca^{2+}-ATPase enzyme system. Similar alteration in the steroid hormone metabolism was demonstrated in brook trout (*Salvelinus fontinalis*) with respect to PCB and Cadmium contamination (FREEMAN et al. 1984). These experiments were designed to show that malfunction of steroid hormone metabolism was a more sensitive method of detecting heavy metal and pesticide pollutant impacts well before stress and mortality set in. In some streams in Europe all male members of Salmon populations were found sterile, the first signs of the development of this condition being manifested by their production of vitelline, a protein associated with egg production in the females. Male turtles and alligators have undergone sex changes, resulting in loss of reproductive capacity. In alligators' ovarian follicles DDE has been shown to cause multiple gametogenesis per follicle, with incidences of polynucleated gametes. Embryos from such eggs are unlikely to survive (RALOFF 1995b). The important observation in these issues is that the pollutants need not be present in large amounts. Thus, with special reference to persistent pesticides, even when pollutant application or emission has ceased, these sublethal impacts will continue to operate in the ecosystem perhaps for several decades. The impacts cited in these observations are being noticed now, whereas the use of pesticides like DDT was banned more than two decades ago in the Western World. These aspects of the sublethal effects of pollutants would go unnoticed in a survey designed to detect impacts at the stress and mortality levels.

In spite of its extensive application in tsetse and malaria control the environmental effects of such large scale usage of DDT in Zimbabwean environment have not, until recently, been evaluated. There are several studies of DDT in tropical Africa (OSIBANJO et al. 1994, CALAMARI and NAEVE 1994). These reports have mainly documented levels of the pesticide in the African environment. Between 1988 and 1990 the Natural Resources Institute (NRI), made a study of impacts of DDT application in the Zambezi valley, culminating in the report *DDT in the Tropics* (DOUTHWAITE and TINGLE 1995). This is the first attempt to evaluate the ecological impacts of DDT in tropical Africa. In this regard it is indeed a welcome and timely contribution.

8.2 Summary of impacts

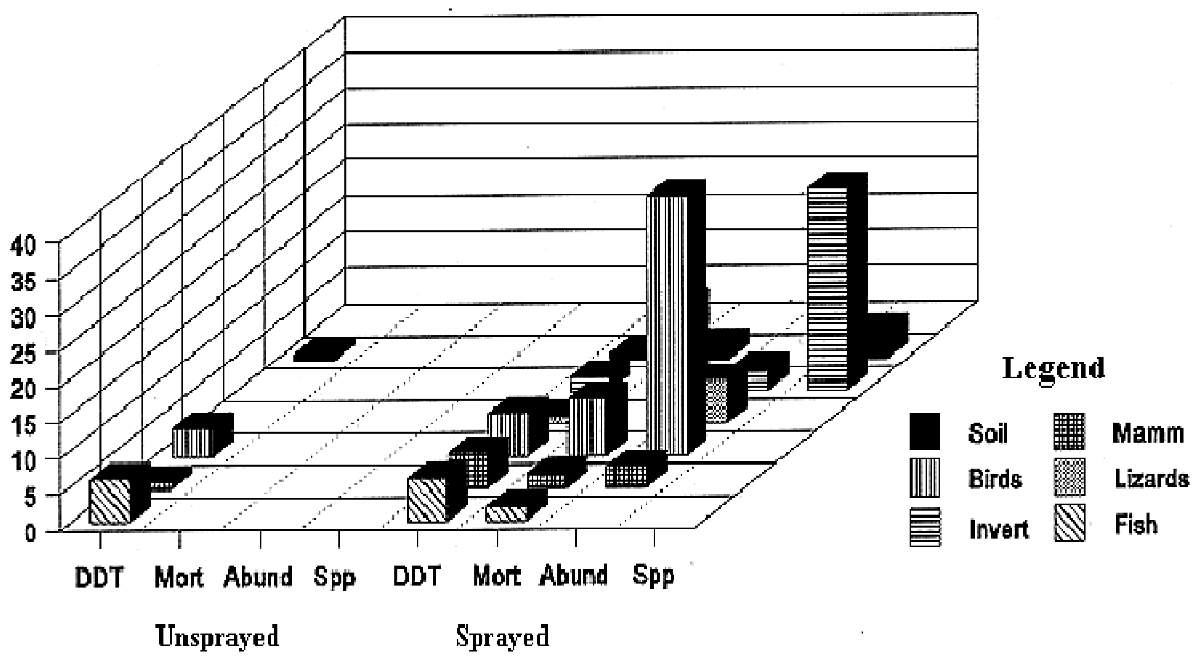
In this review I have attempted to construct an overview of impacts to compare with those stated in the report conclusions of DOUTHWAITE and TINGLE (1995).

The method consisted of noting impacts recorded in the report summary and weighing them from one to four according to the following impact levels:

Table 8-1: Weighing values used in synoptic assessment of DDT impacts

Impact category	Weighting
Bio-accumulation	1
Mortality	2
Population reduction	3
Species loss	4

Figure 8-1: DDT impacts summary



It should be noted that the weighting of the more severe impacts could be underestimated, since the intertrophic bio-multiplication is logarithmic, i.e. the multiplying factor is in orders of magnitude, rather than simple arithmetic progression. However the sum of the impacts incidences at each trophic level, multiplied by the weighing factor, should give an impact category severity index for that trophic level.

The results are shown in Figure 8-1. They show that in the unsprayed area there was measurable bioaccumulation in the soil, birds, mammals and fish. However there were no detectable impacts of mortality, population decline or species loss. It is common that impacts of DDT are often detected some distance away from the area of application, either through the movement of the affected animals or DDT transfer through volatilisation and resorption in the environment. In Zimbabwe DDT has been found in birds eggs in the Victoria Falls area when there had been no known application of the pesticide near the nests recorded.

In the sprayed area there was bioaccumulation at all trophic levels, increasing in instances with trophic station. Bird species showed the most severe population reductions, presumably due to measurable mortality due to ingestion of contaminated invertebrates and fish. Among invertebrates the most severe impact was species loss in both soil and epigeal species.

In all the graphs it shows that while impacts of DDT could be detected in the untreated areas as bioaccumulation, all taxa in sprayed areas showed varying levels of DDT impacts including, in some taxa, species loss. The ratio of the severity impact index in the unsprayed and sprayed areas was 1:10.9. The graph thus suggests that DDT had deleterious effects throughout the entire ecosystem, with the severity of the impacts being more pronounced in some taxa.

The project definition of “landscape” impacts is not clear, but, if the definition is not confined to extreme catastrophes, this rendering of the impacts suggests widespread harm over the whole ecological profile. Thus at a scientific ecological level one cannot but conclude that DDT had adverse ecological impacts. It is important to distinguish between this observation and what we as humans would regard as tolerable "landscape" damage.

8.3 Impacts by trophic levels.

Annex 8-1 is a list of impacts either stated in the report of DOUTHWAITE and TINGLE (1995) or inferred from the data presented in the report.

- **The soil fauna**

The reports cites no significant impacts on soil fauna, although it notes several adverse impacts on soil activity and soil fauna. Figure 8-2 shows the relationship between soil respiration and DDT concentration as reported in Table 2.1 of the report. This graph shows a marked decline in soil respiration with increased soil DDT content.

Figure 8-2: Soil respiration vs DDT concentration

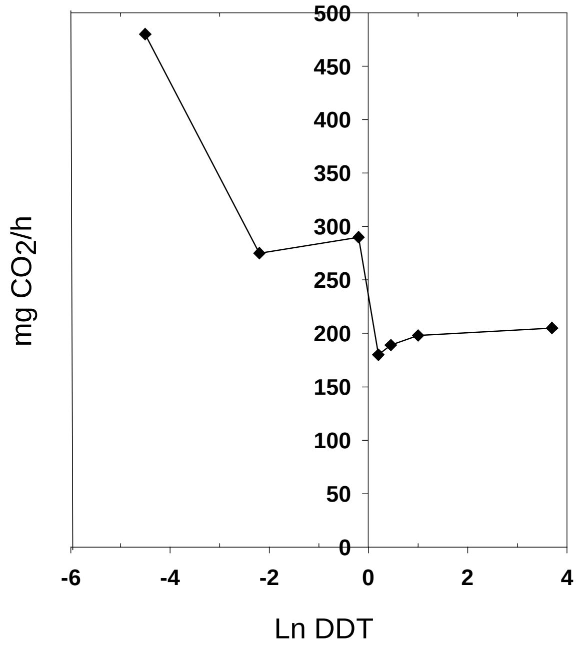
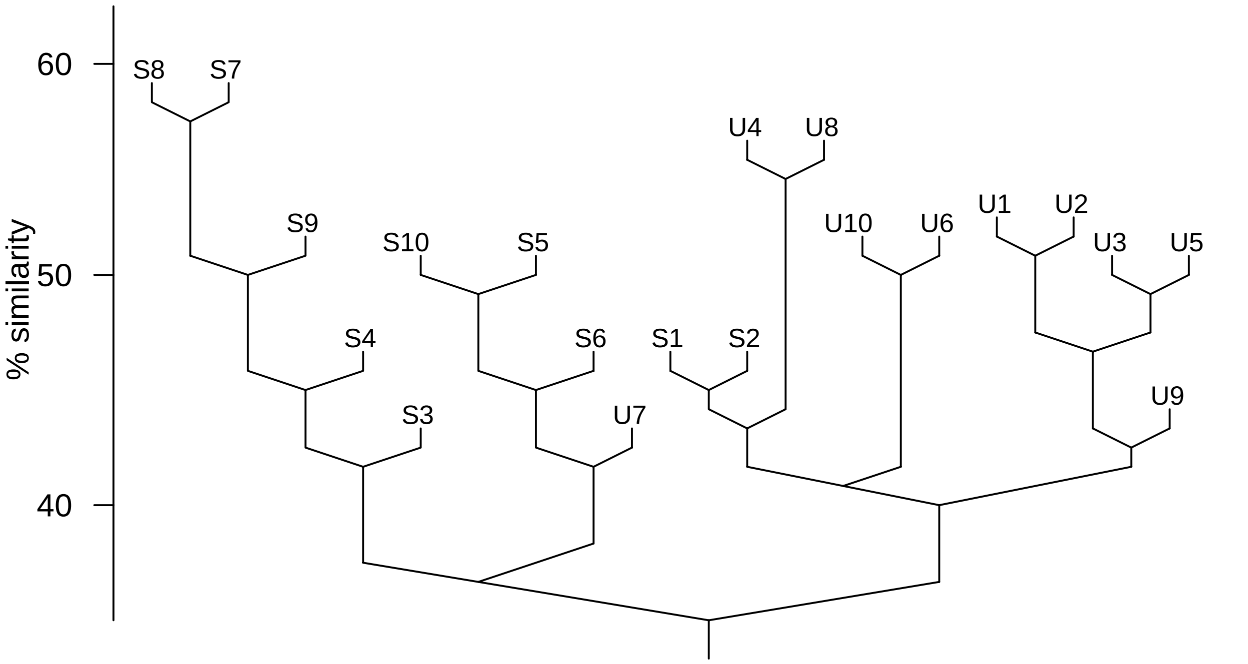


Figure 8-3: Comparison of similarities of sampled areas in sprayed (S) and unsprayed (U) habitats: (from DOUTHWAITE and TINGLE, 1995)



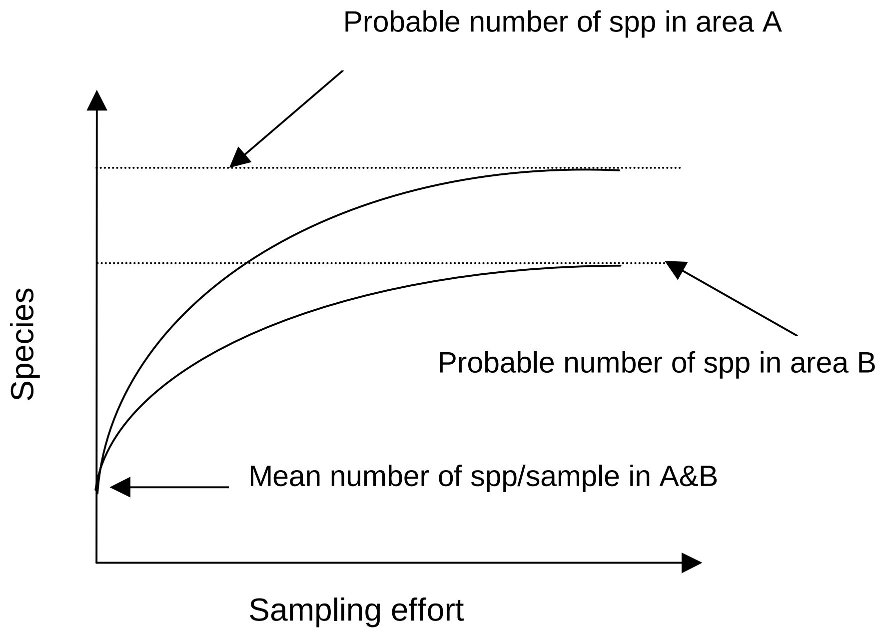
The studies on litter decomposition show that, in appropriate and comparable mesh sizes, litter decomposition in the sprayed area was lower than in the unsprayed area. This suggests lower populations of litter shredders.

In Figures 3.10 a-c of the NRI Report (DOUTHWAITE and TINGLE, 1995), the authors compare the similarity of sprayed and unsprayed habitats, and of the same habitats before and after spray operations. Fig 3.10a, (reproduced here as Figure 8-3 of this review) which is a synoptic analysis of the sprayed and unsprayed areas, shows distinct difference between these areas. In this comparison only one sample from the unsprayed area misclassifies as sprayed while two sprayed area samples misclassify as unsprayed. This is in agreement with Figure 8-1 above which shows some impacts of DDT in the unsprayed area. Figures 3.10 b&c show the comparisons between pre and post spray conditions at the same sites. While in Figure 3.10b it is possible to distinguish between pre and post spray samples, in Figure 3.10c this distinction becomes rather blurred, presumably due to the cumulative effects of the previous spraying impacts. The comparison depicted in Figure 3.10d was presumably designed to show that after the 1988 spray the area would recover sufficiently for the 1989 conditions to be similar to the 1988 pre spray faunal composition. The comparison shows that the impacts of the 1988 spray had persisted to the pre-spray period of 1989. In other words there had been no significant recovery in the intervening year. Furthermore the 1989 pre/post spray comparison shows that the cumulative ecological degradation had developed to a degree where further spray did not produce any significant change in the terrestrial invertebrate faunal composition.

As the similarity index is based on presence/absence only the dissimilarities arise from differences in faunal composition, which here can be attributed to the application of the pesticide. There are thus both spatial and temporal differences between treatments. These changes are reflected in the impairment of litter decomposition under comparable conditions in the sprayed area. The lack of significant difference between the pre and post spray surveys of 1989 indicates cumulative effects of the spray program. This result is in contrast with the claim by MATHIESSEN (1984) that DDT did not accumulate in the environment. If it does not, at least its impacts do.

In Tables 3.3 and 3.4 the report compares mean species (per sample) in sprayed and unsprayed areas. The problem in such a comparison is that the mean number of species per sample is often much less than the total number of species in the study area. Figure 8-4 shows the general relation between number of species and sampling effort. The probable number of species in the area is often estimated by determining the asymptote of a hyperbolic curve of number of species vs sampling effort.

Figure 8-4: Relation between total number of species in a habitat and the mean number of species/sample in that habitat.



In Box 3.5 it is curious why only five samples were available from each area. Small samples as these, with the large sampling errors indicated in Table 3.2, are liable to give capricious results. One would be inclined to work with a more reliable sample size. As the table stands it in fact suggests that spraying was beneficial to the soil fauna. Secondly, as the table shows only total biomass of pitfall catches, why were the samples not simply weighed, rather than estimate their weight from some empirical equation?

In summary, there is sufficient indication of measurable soil fauna deleterious effects. The authors do note that "in general, the density of soil micro-arthropods was lower than in either temperature or African woodlands, but was similar to that in a banana plantation in Uganda," but do not indicate the pesticide application regime in such banana plantations. OSIBANJO et al. (1994) however, indicate liberal use of organo-chlorinated hydrocarbon pesticides in that country. The evaluation could have been improved if the data on soil fauna biomass was reliably determined.

- **Lizards**

The study on insectivorous lizards centred on *Mabuya striata*, the commonest ground lizard in the study area. It showed that populations of this reptile declined progressively with spray intensity. The age distribution was skewed in favor of juveniles, suggesting some significant mortality or reproductive failure among the adults. Tree occupancy in sprayed areas was less than in the unsprayed area. If the juvenile population had suffered the same magnitude of mortality as the adults by a prolonged spray program then the population would have declined significantly. In other words, at least for *Mabuya striata*, a persistent spray program could have led to possible local extinction of the species in the sprayed areas.

No large scale mortality of this lizard is actually recorded in the study, to account for the reported population decline. This could be because dead or dying individuals were taken by predators. Alternatively the decline in populations could have simply been the result of reproductive failure due to reproductive hormone disturbance, as suggested by RALOFF (1994). This possibility was not investigated in this study.

- **Birds**

Among woodland birds this study showed:

- Progressive population declines in some bird species in sprayed areas.
- Mortality among some bird species following spray operations.
- Fewer bird species in sprayed areas (6 frequent species in sprayed area in comparison to 23 spp. in unsprayed).
- 88% decline in black chat population over 33 months after cessation of spraying in sprayed area in comparison to 13% decline in unsprayed.
- Prolonged retention of high DDT burdens in birds in the sprayed areas.

Among predatory birds the study showed:

- Classical symptoms of egg shell thinning.
- Decline in populations and high nest desertion in the African Goshawk in sprayed areas.

HARTLEY and DOUTHWAITE (1994) discussed the impact of DDT in the operational area on the African Goshawk. They found levels of DDT in excess of 130 ppm, a level associated with population declines in raptor populations. They concluded that the high nest desertion rates, and egg shell thinning indicated that tsetse fly spraying caused population decline in this bird. Similarly CRICK (1990), discussing DDT usage in Africa, noted that though the pesticide might appear to be less long lasting in the African tropics, its ecological impacts have longer term effects. In an unpublished manuscript (catalogued as R8427 at the Department of Parks and Wildlife Management

Library, Zimbabwe), CRICK and DOUTHWAITE noted that out of 22 woodland birds species eight were significantly less abundant in the sprayed area.

We can thus conclude that both passerine and raptorial birds suffered adverse effects from the spray program, with some impacts still showing severe population effects nearly three years after cessation of spraying.

- **Fish**

In comparing the impacts of DDT on the fish populations in the study area it is pertinent to note that all the species studied in the Songu river are migratory during the rainy season for spawning. Noting that the distance between the sprayed and unsprayed areas is only just over a kilometer (Fig 4 in DOUTHWAITE and TINGLE 1995) it may have been difficult to obtain fish populations that were entirely confined to the respective treatment areas. This would tend to obscure the impacts of the spray program. Similarly in Lake Kariba MABAYE (1994) has shown that the territory of an individual *Seranochromis codringtonii* can be as much as 40 ha, suggesting a large degree of mingling.

Secondly catch per unit effort, for population comparisons in this study, has several disadvantages, the main one being that it gives highly variable results (RICKER 1975). It is a useful indicator only when a large sample over several years is considered for analyzing population trends.

Thirdly although the authors point out that none of the species encountered in the study are endemic to the study area many river stretches now no longer host any native fish species because of siltation. River courses in protected areas have thus become very important in genetic conservation, and injury to fish populations in such habitats can lead to local extinction of populations that are becoming increasingly fragmented.

With respect to the findings of the study, the data show that:

- There were higher DDT residues in fish from sprayed areas, some at near order of magnitude differences than from unsprayed area.
- Growth index in the 1984/85 growing season was higher in unsprayed area in Red-eye Labeo.
- Mortality factors of Red Eye Labeo estimated from length frequency was higher in sprayed areas, with those in older fish being higher than younger age groups. Mortality rates in the Red Eye Labeo were higher in 1988 spray year than in subsequent years, indicating an initial selection of more susceptible individuals.

- Mortality by year classes in sprayed areas were higher for I+ and III+ age classes, while in unsprayed area Red Eye Labeo fish lived longer than in sprayed area.

In the summary section of the report the authors seem to imply that though fish were found with high DDT burdens it caused them no perceptible ill effects, and in one instance (p 20) they imply that high DDT residue in the environment enhanced survivorship of the parrot fish.

Table 8-2 shows the relationship between DDT burdens and fry mortality in salmon in New Zealand. The DDT burdens cited in the DOUTHWAITE and TINGLE report (1995) and in BERG and KAUTSKY (1995) are much higher than those shown in Table 8-2. On the other hand the mortality rates calculated in the DOUTHWAITE and TINGLE NRI report are derived from field data on the analysis of length frequency and catch data. These techniques produce age specific mortality rates and are unable to detect larval mortality caused by eggs that are over burdened by toxic substances.

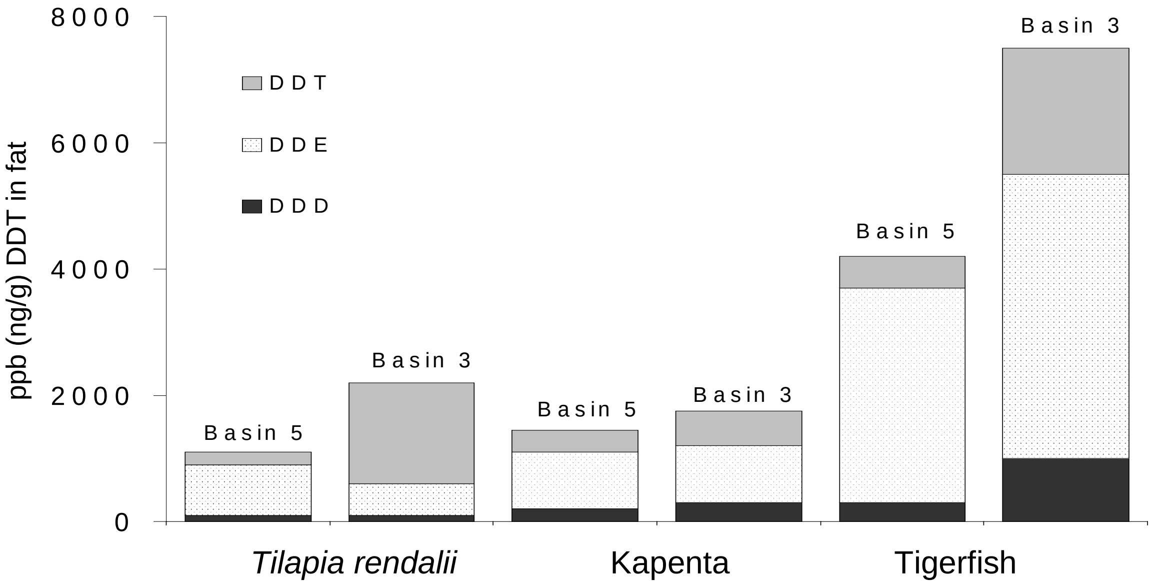
Table 8-2: DDT burdens in *Salmo gairdnerii* in New Zealand and survival of fry.

DDT in ovary;µg g^{-1}	% survival
0.31	89.1
0.39	90.8
0.50	97.1
0.83	91.2
3.47	67.8

(adapted from SAMIULLAH, 1990, data from HOPKINS et al, cited in SAMIULLAH, *loc cit)*

- **Fish (Kariba Lake)**

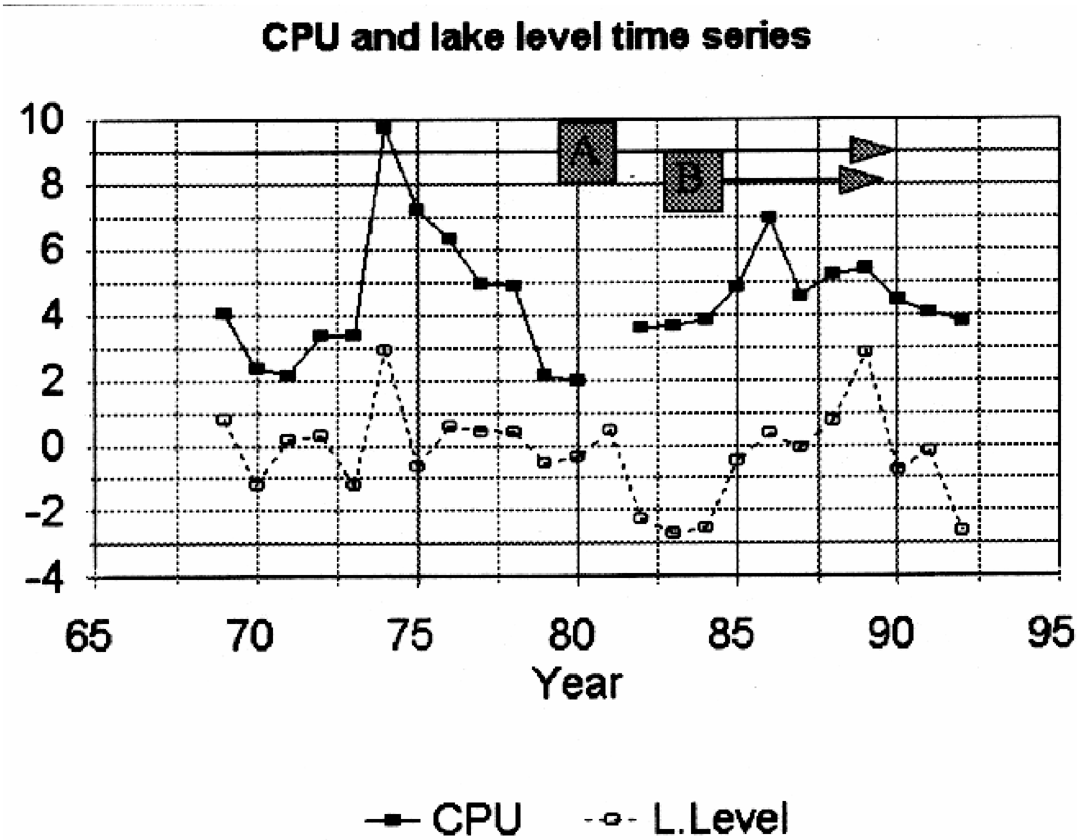
Figure 8-5: DDT and derivatives in three common fishes from two basins of L. Kariba (BERG and KAUTSKY, 1995)



Comparison between sprayed and unsprayed areas in L. Kariba are not easy. Data from ZARANYIKA et al. (1994), and BERG and KAUTSKY (1995) seem to suggest that DDT is now widespread in the lake; at least it would be difficult to distinguish between different localities in the Sanyati basin. Thus lack of statistically significant differences between shoreline localities adjacent to sprayed areas in contrast to those next to unsprayed areas, and taking note of the possible mingling of fishes from such areas, does not necessarily reflect lack of impact in the hinterland. Furthermore data on DDT residues in fish from L. Kariba from Basin 3 and Basin 5 also support this view (BERG and KAUTSKY 1995, Figure 5).

Figure 8-6 shows the relation between catch per unit effort (CPU) and lake levels in L. Kariba. The data refer to the whole lake, so that local impacts from more contaminated waters would not be reflected. The graph shows two periods of significant CPU decline in the lake, one in the post 1974 period and the other ten years later in the post 1984 period. RICKER (1975) points out that large and sudden changes in CPU are probably an indication of changes in survivorship. The exact chronology of the spray program in the Zambezi valley adjacent to L. Kariba is not clear but indications are that these periods correspond to concerted efforts to rid the valley of the fly using DDT. The annual yields of L. Kariba fishery have been correlated with lake levels or run off into the lake (MAGADZA 1994, SADC Fisheries Project 1993). In Figure 8-6 the correspondence between changes in lake level and CPU is only convincing in the 1974 season. It thus appears that the large fluctuations in CPU shown in Figure 8-6 may be partly due to hydrological events but also due other extrinsic source of mortality, such as that indicated in Table 8-2. A convincing argument that African fishes can carry large DDT burdens without ill effects would have to come from carefully controlled experimental data, rather than field observations alone.

Figure 8-6: Variation of Catch per Unit Effort with Lake levels in L. Kariba for the inshore fishery[2]



One of the recent discoveries on the effects of some chlorinated hydrocarbons is their ability to mimic sex hormones and cause sex hormone imbalances (RALOFF, 1994, 1995a, 1995b). Table 8-3 shows a curious imbalance in the ratio of males and females of *Synodontis zambeziensis* at the sexual maturity stage iv, when they are described as “active” (SANYANGA et al., 1995). The overall sex ratio was found to be 57.4% females to 42.6% males, but the average proportion of those showing sexual maturity was 18.5% females to only 2.1% males. The overall differences in abundance between the sexes

[2] (Data from SADC Zambia/Zimbabwe Fisheries Project, 1993). Arrows indicate periods of spraying as (A) overall programme in the valley and (B) in the study area.

could be explained by differential mortality of fishing gear effect, but the imbalance between sexual maturity may need a separate explanation.

In summary the study has indicated some adverse effects of DDT on fish species in the inflow streams to L. Kariba. The potamodramous behaviour and movement patterns in the lake of fishes, and the now ubiquity of DDT residues in the lake, make it difficult to detect site specific impacts. Conclusions that the spray program had no significant impacts, based on site specific comparisons, are at least questionable.

Table 8-3: Comparison of % sexual maturity in *Synodontis zambeziensis* in L. Kariba (after SANYANGA 1995)

Month	% Females above stage 4	% Males above stages 4
January	-	-
February	-	-
March	59.9	10.3
April	37.3	6.7
May	7.7	0.0
June	28.1	0.0
July	8.2	1.1
August	18.4	0.7
September	0.0	0.0
October	0.4	0.6
November	3.0	0.0
December	21.6	1.4
Average	18.46	2.08

- **Bats**

Table 8-4: Comparison of bat species found in NRI study and those given in SMITHERS (1983) for the area.

Genus	Food	Habitat	Smithers	NRI	Difference
Epomophorus	Fruit	rf;f;s	2	0	2
Rousetts	Fruit	c	1	0	1
Tophozous	Insects	s	1	0	1
Otomops	Insects	s	1	0	1
Tadarida	Insects	s;c	9	7	2
Miniopterus	Insects	c	2	1	1
Pipistrellus	Insects	rf	4	3	1
Chalinolobis	Insects	s;rf	1	0	1
Laephotis	Insects	s;rf	1	0	1
Eptesicus	Insects	s	6	4	2
Scotophilus	Insects	s	2	1	1
Nycticeius	Insects	s	1	1	0
Kerivoula	Insects	rf	2	1	1
Nycteris	Insects	s;f;rf	6	2	4
Rhinolophus	Insects	s;c;f;rf	8	7	1
Hipposideros	Insects	s	2	2	0
Cloetis	Insects	c;s	1	0	1
		Total	50	29	21

Key to Habitat: rf = riverine forest; s = savanna woodland; f = forest; c = cave.

By listing bat species that could be found in the Zambezi valley area, according to SMITHERS (1983), and comparing the list with the number of species found in the study, it is possible to gain some idea of the correspondence between expected and observed bat species diversity. Table 8-4 makes such comparison.

Figure 8-7: Bat species abundance against sampling effort; unsprayed area

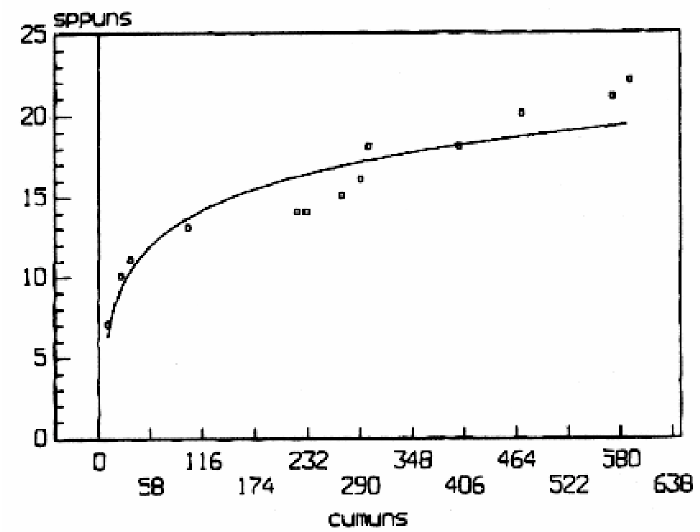
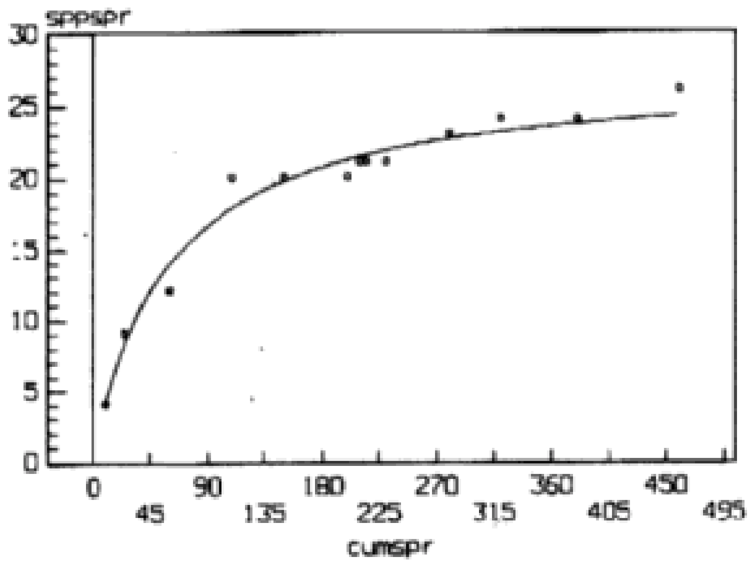


Figure 8-8: Bat species abundance against sampling effort; sprayed area



Using data from Figure 6.1 in the report, it was possible to estimate the number of species found in each area. It should be pointed out that the analysis presented here is based on data obtaining by reading off data points in the species abundance graph given by DOUTHWAITE and TINGLE (1995). There could be inevitable interpolation errors.

The method used to find a suitable regression fit to the data, with following restrictions:

- It has an asymptotic value, denoting the possible number of species.
- It does not grossly violate both the SMITHERS data and the number of species observed in the NRI study.

The best fit for the sprayed area was a hyperbolic model that gave an asymptotic value of 27 species. The estimate agrees well with the thirty-odd species listed in the NRI report, table 6.1. For the unsprayed area the best fit was a linear equation, but obviously there is not an infinite number of bat species in that area. Thus the next best fit, a logarithmic model, gave an estimate of 51 species, giving a good agreement with SMITHERS' data. The models were as follows for sprayed and unsprayed areas respectively (Figure 8-7 and Figure 8-8):

$$\mathbf{Y = X/(2.1114 + 0.03651X): R^2 = 0.997} \text{ (Sprayed); (est.= 27 spp),}$$

$$\mathbf{Y = -1.11 + 3.216\ ln(x); R^2 = 0.876} \quad \text{(Unsprayed); (est. 51 spp).}$$

Box 1: DDT impacts on bats (extract from the NRI study)

> Computed proportion of bats at risk of mortality due to DDT brain residues ranged from 100% to 38% in sprayed area, and 0% in unsprayed (p.112).
>
> Population declines in sprayed areas of *Eptesicus somalicus* attributed to DDT (p.121).
>
> Evidence of reproduction failure in colony of *Rhinolophus hidebrandtii* in area sprayed for 4 times. This was due to juvenile mortality due to high DDT residues (p.116, Box 6.5.5).

The difference between the number of species found by SMITHERS in the L. Kariba area and those recorded in the NRI study (Table 8-4), when added to the estimated number of species in the treated area (Figure 8-8), would add to 48 species. This further suggests that the full complement of bat species in the operational area before spraying was around fifty-odd species. In other words some twenty odd species have to be accounted for. DDT has been implicated in the dramatic population decline of bat populations in the USA (MCEWEN and STEPHENSON, 1979), where bat cave populations declined from several millions to a few hundreds of thousands. Experimental data showed that young bats were poisoned by mobilisation of DDT derived from mothers' milk.

It is also notable that the habitats of most of species unlisted in NRI is often riverine vegetation, which would be of particular attention to the spray applicators. Some bat species seek refuge in caves and overhanging rock faces, which are rather restricted habitats in the operational area, rendering the inhabitants of such hideouts particularly vulnerable to loss of habitat by DDT contamination.

Several species have discontinuous distribution, probably occurring in discrete populations around suitable habitats such as water holes. Such isolated populations would also be quite vulnerable.

These data suggest that there could be a greater difference in species richness between the sprayed and unsprayed areas. Further, the data suggest that the unsprayed area was probably under sampled, hence the lack of a convincing inflection in the species abundance curve.

It is notable that the discussion on population effects centers on those species that were most abundant. It also shows that several specimens of such abundant species had DDT residues that would be lethal at low body fat status. It is therefore conceivable that populations of the less abundant species could have been severely reduced without being noticed.

8.4 Summary

This study has identified adverse effects of DDT application in the Zambezi valley at all trophic levels. These impacts range from mere DDT bio-accumulation through population declines to loss of species. The study monitored the impacts of DDT application over a limited time span, rather than the effects of prolonged and sustained applications, as say in a pest control fanning system. However the limited application of DDT in this context has elicited all the impacts observed in prolonged applications. Some impacts have had limited duration, while others, such as the DDT burdens in some birds as well as population reductions and egg shell thinning, appear to persist well after the termination of the spray program, with no predictable period of recovery.

It is precisely because of the apparent "short lived" impacts that the authors have argued that DDT usage in the African tropics might not be as harmful, in the long term, as in the temperate zone. In the temperate areas the impacts observed were the result of at least 20 years of persistent usage of the pesticides, whereas the effects observed here are from intermittent use over a period of about 10 years in the study area.

One argument raised in support of the spray program was the projection that DDT levels and effects could disappear in twenty to thirty years rather than the fifty years or so for temperate climates, and therefore its impacts are temporary and recoverable. In this regard it is pertinent to make the following observations:

1. The tsetse fly is spread over a much wider area than the study site. If DDT were to be the mainstay of tsetse control in the region local extinction rates would be higher, since species loss would not be compensated by immigration from nearby untreated area.
2. The fly control program has spanned 22 years. If DDT is periodically used to control the fly then the decay period is advanced another 20 - 30 years. The data suggest that in that time some species could have suffered local extinction. In area one, at least five years after the end of the spray program it is still necessary to deploy odour baited traps, presumably because the fly has not been eradicated. Thus if DDT had remained the preferred method of fly control, the spray program would have continued for some years, each time making it less probable that the ecosystem would recover to its pristine condition in the 20 to 30 years stated in the report.
3. The report also notes the loss of a few species and implies that such species would recolonise the treated area sometime after cessation of spraying. The process of species extinction and loss of biodiversity does not result from mass global mortality, but rather the global effect of incidence of localised extinctions. If the findings of this report were to be understood as condoning the use of DDT, and the use of the pesticides in tropical Africa were to increase such that the pesticide was in use simultaneously in several fly control areas, then the integrated effect of such local extinctions as noted in the report could result in regional extinctions. To put the population declines and species losses reported in the DOUTHWAITE and TINGLE report in regional context CRICK (1990) notes that the data on threatened raptors in Africa shows that in Kenya and South Africa as much as five percent of the birds studied had lethal doses of DDT and dieldrin while as much as 12% had sublethal but still potentially harmful level. The pattern of DDT usage in countries between Kenya and South Africa is comparable, so that it is reasonable to assume that these figures are regional, rather than national.
4. The study is altogether lacking in population dynamics studies of at least those species it has shown to be vulnerable at population and species level, to enable some projection of recovery periods of the severely affected

populations. In the black chat for example the population was 88% lower 33 months after cessation of the spray program. Had the spray program persisted for say another two years would the population have survived? Furthermore there is no indication on the direction of the population trends in the post survey period.

Indeed the observed duration of the persistence of the impacts of the pesticide in some species seems to contradict the data presented on page 36, where DDT residues are shown to dissipate in a matter of days. What that data may in fact suggest is simply a change in the partitioning of DDT in the ecosystem, rather than its disappearance altogether. Tsetse control spray areas are usually burned in the dry season. At the beginning of the rains such areas are prone to high erosion rates from thunderstorms. Thus mass transport of DDT bearing erosion products may account for the rapid build up of DDT in L. Kariba.

5. The study did not concern itself with rare species, and indeed we will not know what happened to them. All the species studied in detail, except Arnot's chat, which has a Red Data Book status, are common with wide distributions. However rare species, because of their low population numbers and often restricted distribution, are vulnerable to any process that causes population decline or interfere with successful breeding A number of bird species in the endangered category, such as Rufous Bellied Heron (*Butorides rufiventris*), Whitebacked Night Heron, (*Gorsachius leuconotus*), the Dwarf Bittern (*Ixobrvchus sturmii*), Bittern (*Botaurus stellaris*), Saddlebilled Stork (*Ephippiorhyncus senegalensis*) occur as breeding migrants in the Zambezi valley. They occur in the operational area and feed on the same diet as those species that have been shown in this study to have suffered adverse impacts from the spray program. The Bittern is recorded as now extinct from the southern Cape area of South Africa (MACLEAN 1993). Annex 8-1 lists some reptile species that have restricted distribution in the area and, as in *Mabuya striata*, would have been subject to the same toxicological effects.

6. The study chose representative species of the major ecological niches, but is mute on the extrapolation of the results of such representative studies. Among the Reptilia, for example, the study used *Mabuya striata* as the ecological type. *Typhiacontias gracilis, Lygosoma sundevallit, Mabuya maculliabris, Holapsis guentheri, Hemidactylus rnabouia, Lydodactylus angolensis, L. capensis, L. chobiensis, Pachydactylus bibroni, P. punctatus and P tetensis* are described in BRANCH (1990) as having similar habitats and foraging behaviour as *Mabuya striata*. Similarly *Rhinopomastus*

cyanomelas and *Phoenicilus damarensis* could be regarded as analogues for the Redbilled wood hoopoe. It is thus possible that the effects noted in the selected species could have occurred in their ecological analogues as well.

7. BERG and KAUTSKY (1995) indicate that the level of DDT complex in the L. Kariba fish would not pose a threat to public health, since the daily intake from consumption of such fish would be less than the WHO recommended ADI (allowable daily intake) of 20 µg/kg of body weight. It is interesting to note however that a 50 kg person feeding on a daily intake of 250 g of Kariba fish would on the average consume twice as much DDT complex (0.15 µg/kg of body weight) as his counterpart in USA, UK or Japan, who average 0.062 µg/kg (UNEP 1987, 1989). The L. Kariba intake rates would be closer to those of Guatemala and Hungary. Even more significant is the fact that the WHO guidelines would refer to levels that would cause visible morbidity, rather than the subtle biochemical impacts now unfolding.

8.4.1 Value Systems in environmental impact assessments

There are several stages in an environmental impact assessment (EIA). An EIA is normally requested by project proponents who often may not be scientists, but have to make social, economic and political decisions. The EIA has thus several developmental stages:

- The scientific investigation
- The scientific interpretation
- The value added interpretation
- The socio-political interpretation.

The first stage is the collection of scientific facts, their verification and evaluation, using standard scientific methods of sample design and laboratory procedures. In this instance one would establish the toxicity levels of DDT and its derivatives in the environment, the population status and response to environmental disturbance of prudently chosen indicator species, etc.

The second stage would be a scientific interpretation of such facts, again using scientifically accepted procedures. Here, where the observed facts appear to depart from a predetermined position then the weightiness of such differences are again evaluated by standard procedures, in a way that any other scientists, given the same facts, would arrive at the same conclusion.

The third stage is to place such findings in an overall ecological perspective. At this stage not only would the scientist rely on his experience, but also on the corporate experience of his peers. Here it is inevitable that the evaluators may introduce their own perspectives of what environmental effects would be considered contextually significant impacts. For example the presence of high DDT residues on sprayed tree trunks in this study has been shown to have a cascading effect on the trophic chain.

With particular reference to this study the data indicate:

- High levels of DDT in the soil following spraying.
- Modification of soil fauna composition.
- Some impairment of soil microbiology.
- High DDT loads on insects exposed to the pesticide.
- Population declines in vertebrates (reptilian, avian and mammalia) that feed on such insects.

Other workers' data also show high DDT loads on common commercial fish populations in L. Kariba. These data point to ecosystem wide impacts of the DDT application.

The last stage is the contextualisation of the scientific data in a socio-economic and political environment. Here the scientist meets various stakeholders who may hold certain positions rather passionately and may expect the EIA to uphold their point of view. Impacts are weighed against socio-economic and political gains; against what is perceived as human welfare in opposition to esoteric ecological puritanism.

The loss of soil microbial activity in an agricultural context might be an unavoidable effect if the treatment in fact results in improved agricultural output due to pest control. On the other hand, the loss of a conspicuous bird species might be considered a significant environmental impact due to its tourist value, while the loss of Rhino in Zimbabwe seems to have ruffled no government feathers. In contrast, MARKHAM et. al (1994) express concern over the possible loss of the great raft spider (*Dolomedes plantarius*) due to global warming.

These levels of an impact assessment interpretation often occur in varying promotions according to the bias of the impact assessor. It is therefore important, when reading an impact assessment, to recognize at what levels the various interpretations are made.

In the DOUTHWAITE and TINGLE study the scientific protocols have identified several adverse effects. However the study concludes that the observed impacts are tolerable since they only cause passing pain to the ecosystem. The spray program has had a few casualties but it is in the nature of environmental management for greater human good. The contradiction here lies in the conclusion that in the tropics, at least the semi-arid savanna, DDT can be safely used as a tsetse control tool. The contradiction is the exoneration of DDT in this application on basis of the temporary nature of the impacts (temporary meaning several years), while recommending the use of the pesticide as a safe tool for an all time usage.

The project report states that in order for the effects of DDT to be regarded as having had significant impacts such impacts must be apparent at “landscape” level. Consequently, the study gave priority to vertebrate populations, because at that trophic level the vertebrates would have integrated impacts "at landscape" rather than at site specific levels at lower trophic stages. If indeed the study had shown wide spread significant damage at the vertebrate trophic level (presumably by evidence of significant vertebrate mortality and population declines and extinctions) then the result would have signaled an ecological catastrophe at lower trophic levels of Chernobyl proportions. For the authors to suggest that only then should we consider the impacts significant is gross irresponsibility.

8.4.2 Impacts of other pesticides

- **Endosulfan**

DDT has always been a ground application pesticide in tsetse control. Where topography and vegetation type permit Endosulfan has been applied as a topical aerosol. The first large scale application of this pesticide was in the Western Province of Zambia (MAGADZA 1978). The area is semi arid with very little surface water, except for the Kwando River and isloated pans. MAGADZA found no significant impacts of the application to non target organisms.

The successful eradication of tsetse flies from the Western Province of Zambia led to the application of this pesticide on the Okovango Delta area in Botswana, where considerable fish mortality was reported (MERRON, 1992). Fish are particularly sensitive to Endosulfan poisoning. At the dose rate used in this application the pesticide attained toxic concentrations in shallow water bodies. Similar results have been observed in Zimbabwe (FGU-Kronberg 1988), where peasant farmers who ate intoxicated fish also showed toxicity symptoms. It seems that while Endosulfan can be used for tsetse control with little non target effects in terrestrial systems it can cause considerable non target effects in aquatic ecosystems, and therefore it is not suitable for use where expanses of shallow water bodies form part of the landscape.

- **Acaricides**

The control of tick borne diseases has brought a variety of pesticides on the Zimbabwe market. Furthermore the rapidity with which tick species acquire resistance to such chemicals has meant a quick turnover in the acaricides in use. One notable environmental impact of these chemicals is the virtual extinction of the avian commensals (oxpeckers, *Boophagus spp*) that feed on ticks on large mammals from all areas where cattle exist. Within Zimbabwe these bird species only exist as fragmented populations in wildlife management areas.

8.5 Conclusions

In view of the discussion above I am satisfied that the report has adduced sufficient evidence of measurable ecological damage arising directly from the application of DDT in the Zambezi valley. The persistence and severity of the damage was variable in the different taxa, but not negligible. Furthermore because of the method of selecting representative organisms in each ecological group the results are to be interpreted as giving us a **window** on possibly much wider impacts on organisms that the study had no time to attend to. Other attending secondary effects, such as land degradation (MAGADZA 1986), are of course not discussed in the document.

I cannot agree with the general conclusions of the NRI report that use of DDT in the African tropics is acceptable. The scientist's responsibility is to avoid political entrapment by making irresponsible remarks. While I have indicated some possible improvement in the technical content of the report, my main point of departure with the document is at what I have termed stage three, of the EIA scenario, where the authors have belittled their own findings and made such facetious remarks about the elephant causing more environmental damage than DDT. This then opens the opportunity for an unbridled political interpretation that DDT is a safe and preferable pesticide for the control of the tsetse fly. It also automatically justifies the use of DDT in other pest control programs, not only in the Zambezi Valley of Zimbabwe, but in the tropics in general. Science must avoid being held responsible for tragic outcomes simply by the mismanagement of its data.

References

Anjum, F. J. and M. K. J. Siddiqui (1990): In vitro inhibition of fish *(Tilapia mossambica)* brain Ca2+-atpase by monocrotophos, dimethoate, diazinon and DDT. Indian J. Exp. Biol., 28(5): 488-489.

Berg, H. and N. Kautsky (1994): Persistent pollutants in the Lake Kariba ecosystem- a tropical man-made lake. CIFA/94/Sem.A.8.Harare

Blair Research Institute (1990): Annual Report, 1990. Blair Research Institute, Harare. 148 pp.

Branch, B. (1990): Field guide to the snakes and other reptiles of Southern Africa. Struik Publishers. 326p.

Calamari, D. and H. Naeve (1994): Review of pollution in the African aquatic environment. FAO- CIFA Technical Paper 25, 118p.

Crick, H. (1990): Poisoned prey in the heart of Africa. New Scientist 24; pp. 39-42.

Crick, H. Q. P., and R. J. Douthwaite. (Unpublished manuscript). Tsetse fly control spraying operations with DDT and the abundance of woodland birds in Zimbabwe. Parks and Wildlife Management Library collection item R8427.

Douthwaite, R. J., and C. C. D. Tingle (1995): DDT in the tropics: The impacts on wildlife in Zimbabwe of ground-spraying for Tsetse Fly control. Natural Resources Institute, ODA. 195p.

FGU-Kronherg Consulting+Engineering GMB (1988): Land use study of the tsetse fly infested Omay Communal lands. FGU-Kronberg Consulting+Engineering GMB. West Germany.

Freeman, H. C., Sangalang, G. B., and J. F. Uthe (1984): The effects of pollutants and contaminants on steroidogenesis in fish and marine mammals. In Cairns V. W., Hodson, P. V., and J. 0. Nriagu (eds). Contaminant effects on fisheries. John Wiley & Sons.

Hartley, R. R., and R. J. Douthwaite. Effects of DDT treatments applied for tsetse fly control on the African goshawk in north-west Zimbabwe. Afr. J. Ecol., 32; 265-272.

Mabaye, A. (1994): The biology and behaviour of *Seranochromis codringtonii* in L. Kariba. Ph. D. Thesis, University of Maryland.

Maclean, G. L. (1993): Robert's birds of southern Africa; 6th Ed. Trustees of the John Voelcker Bird Book Fund, Cape Town.

Magadza, C. H. D. (1978): Field observations on the environmental effects of large scale application of Endosulfan in the eradication of *Glossina morsitans centralis Westw.* in the Western Province of Zambia in 1968. Rhod. J. Agr. Res., 16:211-220.

Magadza, C. H. D. (1983): Toxicity of Endosulfan to some aquatic organisms of southern Africa. Zimb. J. Agr. Res. 21.

Magadza, C. H. D. (1986): Conflicts of resource use on the Lake Kariba environs. Nature and Resources, Vol. 22 (4)2-12. UNESCO.

Magadza, C. H. D. (1994): Climate change: some multiple impacts in Southern Africa. Food Policy; 19(2).p 165-191.

Markham, A., Dudley, N., and S. Stolton (1994): Some like it hot: Climate change, biodiversity and the survival of species. WWF international, CH- 1196 Gland, Switzerland. 144p.

McEwen, F. L and G. R. Stephenson (1979): The use and significance of pesticides in the environment. John Wiley Scientific Publications.

Merron, G. S. (1992): Tsetse fly control and the environmental implications for fish in the Okavango Delta, Botswana. Botswana Notes and Records (Gaborone); Vol.24, p. 49-56.

Miskiewicz, A. G. and P. J. Gibbs (1992): Variability in organochlorine analysis in fish: an interlaboratory study and its implications for environmental monitoring and regulatory standards .Arch. Environ. Contam. Toxicol., 23(1):45-53.

Moriarty, F. (1983): Ecotoxicology. The study of pollutants in ecosystems. Academic Press, Inc.

Osibanjo, 0., C. Biney, D. Calamari, N. Kaba, I. L. Mbome, H. Naeve, P. B. 0. Ochumba and M. A. H. Saad (1994): Review of chlorinated hydrocarbon substances in the African aquatic environment. FAO Fish. Rep., No.502. p.7-45.

Raloff, Janet (1994): The gender benders: are environmental “hormones” emasculating wildlife? Science News, 145(2):24-27

Raloff, Janet. (1995a): That feminine touch. Are men suffering from prenatal or childhood exposures to "hormonal" toxicants? Science News 145; pp 56-59.

Raloff, Janet. (1995b): Beyond oestrogens. Why unmasking hormone-mimicking pollutants proves so challenging. Science News 148; pp 44-46.

Ricker, W. E. (1975): Computation and interpretation of biological statistics of fish populations. Department of the Environment, Fisheries and Marine services; Ottawa, Canada.

Samiullah, Y. (1990): Biological monitoring of environmental contaminants: Animals. Global Environmental Monitoring System. MARC Report No 37.UNEP.767 p.

Sanyanga, R. A., et al. (1995): Abundance and distribution of inshore fish in fished and protected areas in Lake Kariba, Zimbabwe. Hydrobiologica 306 (1): 67-78.

Smithers, R. H. N. (1983): The mammals of the southern African subregion. University of Pretoria. 736 pp.

United Nations Environmental Programme (1987): Environmental data report. Basil Blackwell; 352p

United Nations Environmental Programme (1989): Environmental data report. Second edition 1989/90 Blackwell Reference.

Zambia/Zimbabwe SADC Fisheries Project. (1993): Working group on assessment of the inshore fisheries stocks of Lake Kariba. Project Report No 26. Kariba.

Zaranyika, M. F., E. Mambo, K. Leggett and E. M. Mazuru (1994): Organochlorine pesticides in sediment samples of selected river bays in L. Kariba. The Science of Total Environment, 142; 221-226.

Annex 8-1: List of reptilian species with restricted distribution in potential tsetse control areas. (* = endemic)

Family	Common name	Scientific name	Distribution
Pelomedusidae	Okovango hinged terrapin	*Peusios bechuanicus*	Okovango basin
Amphisbanidae	Black round headed lizard	*Zygapis niger*	Kwando, Caprivi
	Zambezi spade snouted worm lizard	*Monopeltis zambeziensis*	L.Kariba area
	Long tailed worm lizard	*Dolophia longicauda*	Caprivi Strip
Scicidae	Bronze Skink	*Mabuya laccertiformes*	Lower Zambezi and adjacent Zimbabwe
Lacertidae	Caprivi rough scaled lizard	*Ichnotopis grandiceps**	Caprivi and adjacent areas
	Emperor flat lizard	*Platysaurus emperator**	N.E. Zimbabwe & adjacent Mozambique
Chameleonidae	Marshall `s leaf chameleon	*Rmpholeon marshalli* *	E. Zimbabwe & Gorongoza
Gekkonidae	Angola dwarf gecko	*Lygodactylus angolensis*	Zambesi basin
	Chobe dwarf gecko	*Lygodactylus chobiensis*	Okovango & Upper Zambezi
	Tete gecko	*Pachydactylus tetensis*	Lower Zambezi valley
	Tsodilo gecko	*Pachydactylus tsodiloensis**	Tsodilo hills

9 Economic Analysis of Substituting the Usage of Methyl Bromide in Zimbabwe's Tobacco and Horticultural Sectors

E. M. Makaudze[1] and S. Z. Sithole[2]

Abstract

Zimbabwe is ranked the second highest user after Egypt of methyl bromide in Africa. A large proportion (over 80%) of the imported methyl bromide is used for fumigating tobacco seedbeds, a significant amount (about 13%) for grain storage and little amount (1%) for quarantine treatment of horticultural export products.

Like most developing countries, Zimbabwe's economy is heavily dependent on agricultural exports particularly tobacco and horticultural exports. Export markets, especially tobacco, are highly competitive and the use of methyl bromide guarantees a quality crop. Tobacco and horticultural exports contribute on average about 6.3% and 0.4% per annum respectively to Gross Domestic Product (GDP).

With an ozone depleting potential of 0.7, methyl bromide is a serious ozone depleting chemical whose use and production must necessarily be phased out worldwide. The Montreal Protocol set the timetable for the phase-out in use and production of methyl bromide. For both developed and developing countries the challenge is to find alternatives which must be environmentally friendly, cost-effective and easy to apply. In this paper an attempt was made to investigate the returns to methyl bromide versus the identified alternatives (i.e. dazomet + EDB and phosphine) using the simple gross margin analysis. The results indicated that for tobacco seed production, methyl bromide give returns in real terms of about ZW$ 4.00/ha higher than dazomet+ EDB. The return-per-dollar invested was ZW$ 0.70 higher for farmers using methyl bromide as compared to its alternatives. If used fumigating horticultural seedbeds for a crop such as strawberries, methyl bromide gives a return two times as high compared to dazomet+ EDB. If used as storage fumigant, the cost for using methyl bromide is ZW$ 0.76 per ton cheaper than phosphine. Further, research has also established that reducing the current application rate of

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50 g/m^2 by 50-60 percent, methyl bromide still yields very acceptable control results. The latter if translated into cost-returns show methyl bromide being ZW$ 40.68/ha cheaper than dazomet+ EDB. In total, the results presented in this paper tend to indicate that due to higher returns as compared to its alternatives, users of methyl bromide will continue to find it attractive to use methyl bromide. Thus the onus for both developed and developing countries if at all they are to realize the phase-out target requirements as set by the Montreal Protocol, is to search for cheap and viable alternatives to methyl bromide. One such alternative that has not been fully investigated is Integrated Pest Management (IPM) technique which according to CORI and TRIOLO (1994) is cheap and easy to apply than methyl bromide.

9.1 Introduction

Zimbabwe is a significant user of methyl bromide. Since its registration in 1956, according to surveys conducted by MILLER and WILKINSON (1995), Zimbabwe is ranked the second highest user, after Egypt, of methyl bromide in Africa. The survey by MILLER (1994), showed (Table 9-1) that about 83% of imported methyl bromide in Zimbabwe is used as a fumigant in tobacco seedbeds, 13% as a fumigant for grains in storage and for export, 3% for soil treatment for flowers, nurseries and seedbeds, 1% for fumigation of tobacco leaf exports and less than 1% for quarantine treatment for horticultural exports, fumigation of export curios and artifacts, etc. The ability and efficacy of methyl bromide in controlling a wide range of pests makes it the most desired and preferred pesticide by users.

Zimbabwe exports more than 90% of flue-cured and burley tobacco production. Traditionally, all tobacco seedlings are grown under seedbed environment treated with methyl bromide. This treatment is specially important to prevent nematode damage which adversely affects the yield quality of the leaf that is eventually marketed. A quality tobacco crop guarantees the country of good export earnings.

Tobacco exports (Table 9-2) have earned the country over US$ 340.0 million (in 1994) in foreign currency earnings; an increase of over 50% since 1985. Tobacco exports on average contribute about 6.3% per annum to Gross Domestic Product (GDP), as shown in Table 9-2.

Table 9-1: Uses of methyl bromide by sector

User Industry	Use of methyl bromide	Quantity used (tons/year)	Methyl bromide used
1. Tobacco	fumigation of tobacco seedbed	500	83%
	fumigation of tobacco leaf exports	4	1%
2. Grain Marketing Board	fumigation of grain in storage and for export	78	12%
3. Horticulture - Cut flowers	quarantine treatment for horticultural exports	12	<1%
- Curios & artifacts	fumigation	1	<1%
Total		595	100%

Source: MILLER (1994).

The horticultural industry, with an annual growth rate of 40%, is one of the fastest growing sectors in Zimbabwe. Horticultural exports have contributed on average about 0.4% per annum to GDP. During the 1994/95 season exports of horticultural products earned the country over US$100 million; this represents more than a 20-fold increase in export earnings since 1985/86 (Table 9-2).

Table 9-2: Value of tobacco and cut flower exports (1985-94)

Year	GDP (ZW$ million)	Flue-cured exports (ZW$ million)	Flue-cured as % of GDP	Cut-flower exports (ZW$ million)	Cut-flower as % of GDP
1985	6505	355.7	5.5	2.5	0.04
1986	7408	406.4	5.5	4.6	0.06
1987	8019	413.0	5.2	10.1	0.1
1988	1,0184	483.4	4.7	21.6	0.2
1989	1,1165	n/a	n/a	29.9	0.3
1990	1,4643	781.6	4.9	45.1	0.3
1991	1,9339	1,485.8	7.7	107.8	0.6
1992	2,3536	2,071.1	8.8	131.3	0.6
1993	3,1091	2,240.5	7.2	184.1	0.6
1994	3,9775	2,856.9	7.2	346.7	0.9

Source : CSO & HPC

The Grain Marketing Board (GMB) is also another important user of methyl bromide. About 14% of total methyl bromide imported in 1994 was used for the fumigation of grain in storage as well as quarantine treatment for grain exports. Fumigation of grain exports is usually done at the request of the importing country (e.g. Japan).

9.2 Economic importance of methyl bromide to Zimbabwe

Zimbabwe's economy, like the economies of most developing countries, is heavily dependent on agriculture and agricultural exports. Thus, the exports of tobacco and horticultural products play a crucial role in generating the much needed foreign currency, employment and income.

But, at some stage during the production and marketing phases of these products, methyl bromide is used. Firstly, in the case of tobacco, pre-treatment of seedbeds ensures: (i) a good yielding and quality tobacco crop and in turn (ii) guarantees a good return. Secondly, if used as a quarantine chemical for horticultural exports, methyl bromide ensures: (iii) pest and disease-free products and for marketing purposes this (iv) restores customer's satisfaction and confidence. Thirdly, if used for fumigation of durable commodities such as grain in storage, methyl bromide ensures: (v) reduced losses due to storage pests and (vi) guarantees national food security. In sum methyl bromide is essential to agricultural production, commodity storage and pre-shipping treatment of export products.

Despite the economic importance of methyl bromide particularly to developing countries, the use of methyl bromide must be phased out. First identified in 1985 as a serious ozone depleting chemical, with an ozone depleting potential of 0.7 (MBTOC, 1994) methyl bromide is classified as a class I substance that necessarily must be phased out. The estimated ozone depleting potential of methyl bromide is 50 times that of chlorine (UNEP, 1995).

Montreal Protocol (1992, 1995) has set a timetable for the phase-out of methyl bromide, both for developed and developing countries. As presented in Table 9-3 below, the phase-out requirements for developed nations stipulate a 25% and 50% reduction in production and use of methyl bromide by year 2001 and 2005, respectively. A complete 100% phase-out is scheduled 2010. The developing countries on the other hand, are required to freeze consumption of methyl bromide at average 1995-98 levels by the year 2002.

Table 9-3: Phase-out timetable for methyl bromide (Montreal Protocol, 1997)

Country/Region Specific	Period to phase-out	Requirements
USA	complete phase out by 2005	
European Union	Step 1: 60% reduction in 2001 Step 2: 75% reduction in 2003 Step 3: phase out by 2005	
Switzerland, the Netherlands, Germany		successfully phased-out the use of methyl bromide as a soil fumigant
Other industrialized nations	Step 1: 25% reduction in 1999 Step 2: 50% reduction in 2001 Step 3: 70% reduction in 2003 Step 4: phase out by 2005	a stepwise reduction (based on 1991 levels) in production and use of methyl bromide until its complete phase-out in 2005
Developing nations	Step 1: 20% reduction in 2005 Step 2: phase out by 2015	required to reduce consumption to baseline average levels of 1995-98 by year 2005.

9.3 Gross margin analysis of methyl bromide vs. identified alternatives

Currently there is no single alternative that can replace the multiple uses of methyl bromide. Hence the biggest challenge facing both developed and developing countries is to develop superior substitutes to methyl bromide which necessarily must be: (i) non-poisonous to the environment, (ii) cost-effective, (iii) non-toxic to users and (iv) easy to apply.

In Zimbabwe, feasible substitutes to methyl bromide include dazomet and ethylene dibromide (EDB) whose pest control capabilities are summarized in Table 9-4. Dazomet is considered a potential alternative to methyl bromide. Like methyl bromide, it does have nematicidal, fungicidal and herbicidal effects, but is not capable of controlling soil-borne diseases. EDB is also another potential substitute effective at controlling soil-borne diseases and nematodes but is not capable at controlling fungicides and herbicides.

Practically this limitation is overcome by applying EDB in combination with other chemicals, mainly dazomet. But perhaps the important issue is how cost-effective are these identified alternatives versus methyl bromide.

Table 9-4: Identified alternatives to methyl bromide

User industry	Alternative(s)	Control capability
1.Tobacco	Dazomet	like methyl bromide a soil sterilant which has nematocidal, fungicidal and herbicidal effects
2. Tobacco	Etheylene Dibromide (EDB)	controls nematodes and soil-borne diseases
3. Horticulture	Dazomet and EDB	same as discussed above
4. Grain Marketing Board	Phosphine	used for the fumigation of grain in storage

Gross margin analysis is one of the common decision-making tools that farmers employ in deciding what crop to grow and how much. This is because it provides a good indicator of farm viability and profitability. In this section gross margin approach is used to measure the returns to tobacco farmers for using methyl bromide as compared to the identified alternatives.

9.4 Data consideration

Data pertaining to tobacco seed production are collected for the period of 1990 to 1997 farming seasons, which include yield, tobacco output prices, variable costs of different farming activities which include chemical as well as labor costs (see Tables 9-5 and 9-6). In order to measure the returns pertaining to the usage of the three soil fumigants vs. methyl bromide, dazomet + EDB, all other costs are held constant, and what is allowed to vary are fumigant varieties plus the accompanying costs. The results are presented in the section below.

9.5 Results

The gross margin results of methyl bromide versus its potential substitutes of dazomet+ EDB, as fumigants used in tobacco seedbeds are given in Tables 9-5 and 9-6. Results show that methyl bromide gives gross-margin averaging about ZW$ 4.00/ha higher than dazomet + EDB. Return-per-dollar invested was also used to compare the likely returns to farmers of using methyl bromide versus dazomet+ EDB. Results in Tables 9-5 and 9-6, indicate that on average methyl bromide gives a return of ZW$ 34.85 per every dollar invested compared to ZW$ 34.17 of dazomet+ EDB. In other words per every dollar invested the farmer, by using methyl bromide, is realizing a return of about ZW$ 0.70 higher than the alternatives. Thus, by using methyl bromide, not only are farmers enjoying the efficacy of methyl bromide in controlling soil borne diseases, nematodes and fungicides, but are also assured of higher returns.

Table 9-5: Gross margin results using methyl bromide

1.GROSS REVENUE	1990	1991	1992	1993	1994	1995	1996	1997
Yield kg/ha	2253.00	2542.00	2512.00	6666600	2510.00	2664.00	2480.00	2244.00
Output price $/kg	6.49	9.38	4.62	3.59	5.05	5.38	5.36	5.46
Gross Return	14622.0	23844.0	11605.4	9477.60	12675.5	14332.3	13292.8	12252.2
2.SEEDBED VARIABLE COSTS								
Soil Fumigants								
Methyl Bromide price $/kg	11.21	9.95	9.87	15.13	14.60	13.17	12.29	11.56
Application rate kg/ha	6.00	6.00	6.00	2.68	6.00	6.00	6.00	6.00
cost per ha	67.26	59.71	59.25	90.75	87.59	79.00	73.73	69.33
Farming activities								
Tobacco seed required	13.44	11.48	22.63	35.19	23.77	22.38	21.50	20.68
1 Roaming	0.26	0.27	0.24	0.24	0.25	0.25	0.24	0.25
2 Ploughing	2.98	3.06	2.72	2.70	2.79	2.76	2.75	2.80
4 laborers making up beds	3.15	3.23	2.88	2.86	2.96	2.92	2.91	2.96
3 laborers applying ferts	1.77	1.82	1.62	1.61	1.66	1.64	1.64	1.67
Cost of S fert	7.56	7.76	6.91	6.85	7.10	7.01	6.98	7.11
Nitrate of Soda 20kg/sq.mt	2.18	2.24	1.99	1.98	2.04	2.02	2.01	2.05
Chemicals								
198 gas/bed baytan	59.35	57.42	80.37	102.72	74.13	71.31	60.05	66.11
32 gas/bed dyrene	15.84	18.26	36.94	43.51	32.22	32.10	29.73	27.32
12.5 gas/bed dithane	4.82	4.49	3.94	1.70	1.75	1.78	1.60	1.66
30 gas/bed orthene	7.75	9.59	11.06	19.36	14.25	15.28	12.43	15.56
40 gas/bed copper oxychloride	3.38	3.09	3.26	3.95	4.49	5.51	5.42	5.42
54 mlts/bed monocrotophos	25.56	26.24	23.38	23.18	24.05	26.70	21.78	18.15
4 fumigation tents	10.13	10.40	9.26	9.19	9.51	8.95	7.54	9.48
6 applicators	0.63	0.65	0.58	0.57	0.59	0.49	0.40	0.42
1 sealing tape	0.13	0.14	0.12	0.12	0.12	0.18	0.15	0.07
20 perforated plastic	48.51	49.80	44.36	44.00	45.55	41.97	34.56	36.49
Sowing seedbeds								
5kg/ha of tobacco seed	25.32	25.99	23.15	22.97	23.77	23.47	23.39	23.81
20 laborers for sowing	6.03	6.19	5.51	5.47	5.66	5.59	5.57	5.67
5 laborers for seedbeds	60.24	61.84	55.09	54.64	56.57	55.84	55.65	56.65
7 laborers for grass mulch	2.98	3.06	2.72	2.70	2.79	2.76	2.75	2.80
TOTAL VARIABLE COSTS	369.25	366.70	397.99	476.24	423.62	409.90	372.78	376.45
GROSS INCOME	14252.7	23477.3	11207.5	9001.36	12251.9	13922.4	12920.0	11875.8
Return per dollar invested	38.60	64.02	28.16	18.90	28.92	33.97	34.66	31.55

Source: Zimbabwe Tobacco Association (ZTA)

NB: All figures are in real terms

Table 9-6: Gross margin results using Dazomet + EDB

1.GROSS INCOME	1990	1991	1992	1993	1994	1995	1996	1997
Yield kg/ha	2253.00	2542.00	2512.00	2640.00	2510.00	2664.00	2480.00	2244.00
Output price $/kg	6.49	9.38	4.62	3.59	5.05	5.38	5.36	5.46
Gross Return	14622.0	23844.0	11605.4	9477.60	12675.5	14332.3	13292.8	12252.2
2.SEEDBED VARIABLE COSTS								
Soil Fumigants								
Dazomet price $/kg	17.93	18.40	16.40	16.26	16.84	17.39	18.12	18.45
Application rate 3.75kg/ha	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
cost per ha	67.24	69.01	61.49	60.98	63.14	65.20	67.97	69.20
EDB price $/kg	14.62	16.63	19.69	16.08	14.20	12.24	10.24	10.86
Application rate 0.825kg/ha	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
cost per ha	12.06	13.72	16.25	13.27	11.72	10.09	8.45	8.96
Total cost EDB + Dazomet	79.30	82.73	77.74	74.25	74.85	75.29	76.42	78.16
Farming activities								
Tobacco seed required	13.44	11.48	22.63	35.19	23.77	22.38	21.50	20.68
1 Roaming	0.26	0.27	0.24	0.24	0.25	0.25	0.24	0.25
2 Ploughing	2.98	3.06	2.72	2.70	2.79	2.76	2.75	2.80
4 laborers making up beds	3.15	3.23	2.88	2.86	2.96	2.92	2.91	2.96
3 laborers applying ferts	1.77	1.82	1.62	1.61	1.66	1.64	1.64	1.67
Cost of S fert	7.56	7.76	6.91	6.85	7.10	7.01	6.98	7.11
Nitrate of Soda 20kg/sq.mt	2.18	2.24	1.99	1.98	2.04	2.02	2.01	2.05
Chemicals								
198 gas/bed baytan	59.35	57.42	80.37	102.72	74.13	71.31	60.05	66.11
32 gas/bed dyrene	15.84	18.26	36.94	43.51	32.22	32.10	29.73	27.32
12.5 gas/bed dithane	4.82	4.49	3.94	1.70	1.75	1.78	1.60	1.66
30 gas/bed orthene	7.75	9.59	11.06	19.36	14.25	15.28	12.43	15.56
40 gas/bed copper oxychloride	3.38	3.09	3.26	3.95	4.49	5.51	5.42	5.42
54 mlts/bed monocrotophos	25.56	26.24	23.38	23.18	24.05	26.70	21.78	18.15
4 fumigation tents	10.13	10.40	9.26	9.19	9.51	8.95	7.54	9.48
6 applicators	0.63	0.65	0.58	0.57	0.59	0.49	0.40	0.42
1 sealing tape	0.13	0.14	0.12	0.12	0.12	0.18	0.15	0.07
20 perforated plastic	48.51	49.80	44.36	44.00	45.55	41.97	34.56	36.49
Sowing seedbeds								
5kg/Ha of tobacco seed	25.32	25.99	23.15	22.97	23.77	23.47	23.39	23.81
20 laborers for sowing	6.03	6.19	5.51	5.47	5.66	5.59	5.57	5.67
5 laborers for seedbeds	60.24	61.84	55.09	54.64	56.57	55.84	55.65	56.65
7 laborers for grass mulch	2.98	3.06	2.72	2.70	2.79	2.76	2.75	2.80
TOTAL VARIABLE COSTS	381.29	389.72	416.49	459.73	410.89	406.19	375.47	385.28
GROSS INCOME	14240.7	23454.2	11189.0	9017.87	12264.6	13926.1	12917.3	11867.0
Return per dollar invested	37.35	60.18	26.87	19.62	29.85	34.28	34.40	30.80

Source: Zimbabwe Tobacco Association (ZTA)

NB: All figures are in real terms

Further, Tobacco Research Board (BLAIR, 1995) has established that at half the recommended application rate of 50 g/m^2, methyl bromide still yields very acceptable pest control results. The latter, if translated into returns (Table 9-7), indicates that methyl bromide yields gross margin averaging ZW$ 40.68/ha higher than its alternatives.

9.6 Other uses of methyl bromide

As discussed earlier in Table 9-1, about 13% of methyl bromide is used for fumigating grains in storage and for export, 3% for soil treatment for flowers, horticultural fruit, nurseries and seedbeds. However for the same functions, dazomet+ EDB, can be used to substitute methyl bromide. Like in the previous section, the gross margin approach is used to assess the likely return of using methyl bromide for fumigating strawberry seedbeds versus the alternatives. The gross margin results on strawberries are shown in Table 9-7. Methyl bromide yields a two times higher gross margin (ZW$ 556.98/ha) than dazomet+ EDB (ZW$ 260.48/ha).

Table 9-7: Gross margin of methyl bromide at half the application rate

1.GROSS REVENUE	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Yield kg/ha	2253.00	2542.00	2512.00	2640.00	2510.00	2664.00	2480.00	2244.00
Output price $/kg	6.49	9.38	4.62	3.59	5.05	5.38	5.36	5.46
Gross Return	14622.0	23844.0	11605.4	9477.60	12675.5	14332.3	13292.8	12252.2
2.SEEDBED VARIABLE COSTS								
Soil Fumigants								
Methyl Bromide price $/kg	11.21	9.95	9.87	15.13	14.60	13.17	12.29	11.56
Cost per ha at application rate 3kg/ha	33.63	29.85	29.62	45.38	43.79	39.50	36.86	34.67
Farming activities								
Tobacco seed required	13.44	11.48	22.63	35.19	23.77	22.38	21.50	20.68
1 Roaming	0.26	0.27	0.24	0.24	0.25	0.25	0.24	0.25
2 Ploughing	2.98	3.06	2.72	2.70	2.79	2.76	2.75	2.80
4 laborers making up beds	3.15	3.23	2.88	2.86	2.96	2.92	2.91	2.96
3 laborers applying ferts	1.77	1.82	1.62	1.61	1.66	1.64	1.64	1.67
Cost of S fert	7.56	7.76	6.91	6.85	7.10	7.01	6.98	7.11
Nitrate of Soda 20kg/sq.mt	2.18	2.24	1.99	1.98	2.04	2.02	2.01	2.05
Chemicals								
198 gas/bed baytan	59.35	57.42	80.37	102.72	74.13	71.31	60.05	66.11
32 gas/bed dyrene	15.84	18.26	36.94	43.51	32.22	32.10	29.73	27.32
12.5 gas/bed dithane	4.82	4.49	3.94	1.70	1.75	1.78	1.60	1.66
30 gas/bed orthene	7.75	9.59	11.06	19.36	14.25	15.28	12.43	15.56
40 gas/bedd copper oxychloride	3.38	3.09	3.26	3.95	4.49	5.51	5.42	5.42
54 mlts/bed monocrotophos	25.56	26.24	23.38	23.18	24.05	26.70	21.78	18.15
4 fumigation tents	10.13	10.40	9.26	9.19	9.51	8.95	7.54	9.48
6 applicators	0.63	0.65	0.58	0.57	0.59	0.49	0.40	0.42
1 sealing tape	0.13	0.14	0.12	0.12	0.12	0.18	0.15	0.07
20 perforated plastic	48.51	49.80	44.36	44.00	45.55	41.97	34.56	36.49
Sowing seedbeds								
5kg/Ha of tobacco seed	25.32	25.99	23.15	22.97	23.77	23.47	23.39	23.81
20 laborers for sowing	6.03	6.19	5.51	5.47	5.66	5.59	5.57	5.67
5 laborers for seedbeds	60.24	61.84	55.09	54.64	56.57	55.84	55.65	56.65
7 laborers for grass mulch	2.98	3.06	2.72	2.70	2.79	2.76	2.75	2.80
TOTAL VARIABLE COSTS	335.62	336.85	368.37	430.86	379.83	370.40	335.91	341.79
GROSS INCOME	14286.4	23507.1	11237.1	9046.74	12295.7	13961.9	12956.9	11910.5
Return per dollar invested	42.57	69.78	30.50	21.00	32.37	37.69	38.57	34.85

Source: ZTA, Own Calculations

Another important alternative to methyl bromide is phosphine. The latter chemical is used as a fumigant for durable commodities in storage, particularly grain. The Grain Marketing Board of Zimbabwe can use phosphine to fumigate bulk wheat, maize and soybeans instead of methyl bromide. What is of interest is to compare the cost per unit of using methyl bromide versus phosphine. From the results as presented in Table 9-9, it is clear that methyl bromide is ZW$ 0.76/t cheaper than phosphine.

Table 9-8: Gross margin results: Methyl bromide versus Dazomet + EDB in strawberries

Returns:			
Yield (kg/ha)	46.03	46.03	
Price of output (ZW$/kg)	16	16	
Gross return (ZW$/ha)	736.48	736.48	
Inputs	Methyl Bromide	Dazomet	EDB
Costs:			
Application rate (kg/ha)	6	6	0.83
Cost of chemical (ZW$/kg)	30	73.75	40
Total Costs (ZW$/ha)	180	475.5	
Gross Margins (ZW$/ha)	556.48	260.98	

As a longer fumigation time is required for phosphine, there are additional costs such as demurrage and the need for more fumigation sheets. Also shown in Table 9-9 below is the reaction time for methyl bromide versus phosphine. On average methyl bromide requires only 24 hours to fully react compared to 5 days required by phosphine. Further, GMB has also established that by lowering the application rate to 30 g/m^2, methyl bromide still provides very acceptable control results (KUTUKWA, 1996). Once again, on the basis of cost-effectiveness, this makes the usage of methyl bromide very attractive as compared to its alternatives.

Table 9-9: Cost (ZW$/t) and reaction time of methyl bromide vs. phosphine (GMB grains)

Inputs:	Methyl bromide	Phosphine
Reaction time	24 hours	5 days
Application rate (g/t)	0.04	0.0022
Price of input (ZW$/kg)	25	800
Cost (ZW$/t)	1.00	1.76

9.7 Conclusions

Methyl bromide has yielded superior returns both as a seedbed and storage fumigant as compared to alternatives. The gross margin results demonstrated that most of the available chemical alternatives are more costly to use than methyl bromide. Further, efficiency in use of methyl bromide can also be achieved by lowering the recommended application rates by 50% for tobacco seedbed and 25% for grain storage. And even with these reductions, methyl bromide still yields very acceptable pest control results. The latter, from the user's perspective, makes methyl bromide even more attractive to use.

Integrated Pest Management (IPM) has been accorded low research priority, yet some case studies (CORI and TRIOLO, 1994) have concluded that IPM is more cost-effective than methyl bromide. IPM is more desirable than any chemical alternative because it is environmentally sound, offers low potential hazard to users and is cost effective. Thus to meet the phase-out targets of the Montreal Protocol research efforts and resources in search for viable alternatives need to be increased. In particular, research priority could devoted be to IPM because of the attendant advantages that such a method has over chemical alternatives. However, IPM takes a long time to develop as a detailed knowledge of the interrelationships of the pest spectrum with the host/commodity and the environment must be assembled.

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References

Blair, B. (1995): Production of tobacco without methyl bromide in the African environment. Presented at the regional workshop on methyl bromide for English-Speaking Africa. September, 1995.

California Department of Pesticide Regulation, (1994): Restrictions placed on use of pesticide Metam-Sodium and MITC. News Advisory, June 22.

California Department of Pesticide Regulation (1994): Methyl Bromide, Document prepared for the developmental and reproductive toxicant identification, Committee for the Consideration of Methyl bromide as a Development Toxicant under Proposition 65. March 7.

Cori and Triolo (1994): Review of cases of methyl bromide reduction and elimination in Italy. Biotechnology and Agriculture Sector of Technology Innovation Department, ENEA. Rome. London: SAFE Alliance.

Environmental Effects Panel (1994): Environmental effects of ozone depletion: 1994 assessment, United Nations Environment Programme.

Kutukwa, N. (1996): Personal Communication. Grain Marketing Board. Zimbabwe.

Methyl Bromide Technical Options Committee (1994): *1995 Assessment*. United Nations Environment Programme/Montreal Protocol. Kenya.

Miller, M. (1994a): Alternatives to methyl bromide for Kenya and Zimbabwe. Napier, New Zealand.

Miller, M. (1994b): Methyl bromide - Issues for developing countries. London: SAFE Alliance.

Miller, M. and P. Wilkinson (1995) (draft). The economic and trade implications of replacing methyl bromide: Zimbabwe Case Study. Friends of the Earth U.S./Canada.

Shepherd, J. A. (1993): Methyl bromide and tobacco production in Zimbabwe. Tobacco Research Board. Zimbabwe.

Schonfield, A., L. Wamukonya and S. Glendening (1994): Methyl bromide use and alternatives in Sub-Saharan Africa. Pesticide Action Network North America Regional Center.

United States Environmental Programme (1993): The fifth meeting of the parties to the Montreal protocol. Annex VIII, November 17-19, Bangkok.

United States Department of Agriculture (1993): Biologic and economic Assessment of a Methyl Bromide Ban. National Agricultural Pesticide Impact assessment program. Washington DC.

United States Environmental Protection Agency (1994): Methyl bromide consumption estimates. Office of Stratospheric Protection/Methyl Bromide Program. May, Washington DC.

Zimbabwe Ministry of Environment and Tourism (1995): Draft summary and findings. From Regional Workshop on Methyl Bromide for English-Speaking Africa. September 1995.

10 Changes in the Pesticide Industry in Light of Economic Reforms and International Health and Ecological Concerns

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Abstract

The paper examines the changes in pesticide industry as a result of the economic reforms. It reviews the changes in regulations on pesticide importation, formulation, packaging, distribution arrangements and safety awareness measures as well as the risks associated with the use of pesticides in Zimbabwe. The extent to which the FAO International Code of Conduct in pesticide trade, distribution, health and environmental requirements are being met is also examined. The impact of the reforms on pesticide sales and prices are quantified and discussed. It makes recommendations on measures that reduce risks related to pesticide use on both human beings and the environment.

The paper establishes that when used cautiously, pesticides effectively control pests in agriculture and diseases in public health thus minimizing production and storage losses and upholding health and environmental safety. The reform measures saw the increase in players in the pesticide industry leading to competitive importation, distribution and lowering in pesticide prices in US$. However, there was a regrettable weakening in the enforcement or policing of long standing regulations which tie in well with the International Code of Conduct in pesticide registration, distribution and use due to manpower cuts exercise adopted as a cost saving measure geared at reducing public deficit. Although unregistered and incorrectly labeled pesticide products started featuring in retail outlets, human and environment safety has not been seriously compromised. Zimbabwe has succeeded in complying with international agreements on safety measures on restricted or banned pesticides. This has gone a long way in preventing pesticide dumping and environmental pollution. However, difficulties have been experienced in the case of methyl bromide because of lack of appropriate substitutes to support the export earning tobacco and horticultural crops, maize storage and the quarantine system. Concern about excessive use of methyl bromide centers

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on the fact its application in soil fumigation follows preset or routine schedules rather than estimated requirements.

Insignificant increments in the supply of pesticides between 1991 and 1994 are consistent with regulations requiring testing of pesticide for three consecutive seasons and establishment of appropriate infrastructure prior to new suppliers can successfully register and engage in pesticide business. The doubling in quantities and values of pesticides in 1995 marked the entrance of new suppliers. The stabilization of pesticide prices in US$ terms at the start of the reform program and subsequent decline over the last three years, suggest competitive sourcing and improved operational efficiency.

The paper concludes that the increase in pesticide suppliers and the subsequent competitive supply, distribution and lowering of pesticide prices are the positive changes expected from the reform program. However, the supply of untested and unregistered pesticides is an outcome whose negative impact on animal, plant, and environmental safety has yet to be established. Meanwhile, there is a need to strengthen policing mechanisms to ensure that this problem is effectively controlled before it reaches alarming proportions. The use of restricted pesticides of economic importance such as methyl bromide should continue until suitable alternatives have been identified. Suppliers and farmers should be encouraged to provide adequate protective clothing and to use trained workers to handle and apply pesticides to ensure that the reform measures do not impact negatively on the human health and the environment. Finally, farmers should strike a balance between good yields, cost of pesticides, healthy crops, animals and environment.

10.1 Introduction

The use of pesticides to control weeds, insects, fungal and bacterial diseases, mites, nematodes, rodents, snails and birds respectively has made significant contributions to increase agricultural productivity in both smallholder and large scale commercial sector in Zimbabwe (TSODODO, 1997). However, the smallholder sector still experiences in excess of 30% crop losses due to insects and diseases (CHIKWENHERE and SITHOLE, 1993).

Health and environmental safety concerns are raised because pesticides are poisons designed to kill pests and to control diseases. Safety measures are particularly of concern in Zimbabwe because the pressure and hardships facing Government, suppliers, distributors and farmers as a result of reforms is likely to increase the possibilities of;

i incorrect handling and use of pesticides which threaten non-targeted insects, plants and animals,

ii adopting cost saving strategies which compromise measures aimed at enhancing awareness of poisoning risks related to handling and use of pesticides,

iii using cheap pesticides whose use has been either been banned or restricted in other countries,

v using pesticides that take too long to breakdown resulting in accumulation in soil, plants and animals causing ecological imbalances,

vi pesticide dumping by countries wishing to gain market shares lost in countries where the use of the pesticide is banned or restricted,

vii enhancing the production of unadapted commercial crops which require intensive pesticide protection leading to excessive accumulations in soils and water bodies,

viii suppliers cutting costs by supplying unregistered and incorrectly labeled pesticide products with an intention to make quick profit in the face of increasing competition,

ix farmers not providing adequate and proper protective clothing, special handling equipment, using untrained casual labor and not acquiring proper equipment required for effective application of pesticides as cost saving measures,

x unscrupulous activities in the face of the weakening monitoring system caused by manpower cuts targeted at reducing public deficit.

It is against this background that this paper assesses the changes in the pesticide industry in Zimbabwe as a result of economic reforms introduced in 1991. It also examines the extent to which the FAO International Code of Conduct on the distribution and use of pesticides, the Prior Informed Consent, the Montreal Protocol and the maximum residue requirements of Zimbabwe's agricultural trading partners are being met in the changing economic environment.

10.2 The rationale for policy reform

This section highlights the rationale of reforms in the context of pesticide policy, regulations and related safety measures.

10.2.1 Pre-1991 Pesticide policy

Zimbabwe Government's pesticide policy objectives prior to 1991 were aimed at ensuring:

(a) that the right amount and quality of pesticides are available for the agricultural sector at the right time,

(b) that the structure of the industry does not lead to importation of unregistered pesticides that are a hazard to human beings and the environment,

(c) safe and proper pesticide distribution system lead to optimal pricing and make pesticides available for effective prevention of crop damage and livestock losses in both large and smallholder farming areas, and

(d) Government bear sole responsibility of monitoring safe and effective use of pesticides to avoid environmental pollution and human health problems.

10.2.2 Reform policy thrust

The Government officially embarked on the reform program designed to restore and maintain a stable macro-economic environment and to improve local production of key inputs and agricultural commodities in 1991. The poor economic performance was attributed to inappropriate domestic policies including pricing and foreign currency controls, monetary and industrial protection policies which undermined local value adding activities while encouraging fully formulated pesticide imports (GOZ, 1991).

The reforms saw pesticide policy thrust shifting towards;

(a) generating a competitive environment by allowing the market forces to take a leading role in the allocation of financial and non financial resources in determining the quantities, pricing and distribution of pesticides,

(b) Government relinquishing controls and taking a facilitating role for establishing a conducive environment for timely testing and registration of new pesticide products,

(c) liberalization of the foreign currency allocation system to allow competitive sourcing, formulation, distribution and safe use of pesticides, and

(d) involvement of the private sector in reviewing of the legislative framework, monitoring and policing of regulations governing registration, distribution and use of pesticides.

10.3 Structure and changes in the pesticide industry

This section assesses the changes in the structure of the pesticide industry and the administrative arrangements in the importation, formulation and distribution of pesticides.

10.3.1 Structure of the industry

Prior to 1991 the pesticide industry largely comprised subsidiaries of multinational corporations and very few wholly owned Zimbabwe companies (MUDIMU et al., 1995). The establishment of the Zimbabwe Investment Center which greatly simplified the sanctioning of new business activities ushered opportunities for new entrepreneurs to participate in pesticide trading. The new players focused on importation of raw materials, local formulation and distribution of pesticides. Lateral and downstream processing companies also benefited by supplying packaging and labeling materials. Although, the increase in minimum interest lending rates meant to discourage borrowing for consumption initially inhibited investments, the subsequent growth is largely attributed to the removal of duties on capital equipment which eased the purchase of new and replacement machinery.

10.3.2 Importation and administrative arrangements

Prior to the reforms, the industry was characterized by a foreign currency allocation system which seriously undermined utilization of existing productive capacity due to shortages in spares for maintaining existing machinery, raw materials and difficulties in the replacement and upgrading of capital structure. Although, the registration and foreign currency allocation systems were separate administratively, they were linked in controlling the importation and distribution of pesticides.

Foreign currency allocation system

From 1965 to 1990, the industry operated on a foreign currency allocation system. Nearly 200 pesticide products were imported either formulated or as active ingredients for subsequent formulation in Zimbabwe. The range of products more than doubled to 489 between 1995 and 1997 (CSCZ, 1997). This could be attributed to the eased access to foreign currency. While pesticide requirements continue to be drawn from a schedule approved by the Plant

Protection and Research Institute, individual companies are deciding on the quantities of imports and stock levels without seeking approval from the Ministry of Lands and Agriculture (MOLA). Consultations on crop area estimates are being done directly with farmer organizations since the Agricultural Input Priority Committee (AIPC) is no longer functional.

The liberalization of foreign currency, saw the long established companies increasing interest on the aspect of human health and environmental safety factors previously not prioritized in determining the quantities of pesticide imports in an effort to maintain their historical market shares. The availability of foreign currency forced them to compete with the newly established companies which were taking advantage of the flexibility in sourcing of imported raw materials and using latest technology on the market.

It also paved way to unscrupulous traders importing untested pesticides into the country. However, a vigilant authentic local supplier was quick to notify the Ministry of Lands and Agriculture about the marketing such pesticide by leading retail outlets (MOLA, 1997). These included (i) cans labeled Deer Brand Mosquito Coil Incense, (ii) insecticide labeled "kills all insects" and (iii) Baygon with neither registration label nor user instructions.

This incident was very important in sensitizing the Ministry of Lands and Agriculture about the need to strengthen the weakening monitoring and policing mechanisms as a result of gaps arising from the phasing out of the import licensing system. It also marked the beginning in the sharing of policing of pesticide regulations between the private and public sector. This development came in the face of staffing shortages and financial difficulties arising from the downsizing of civil service and budgetary cutbacks, adopted as public sector deficits reducing measures. While the private sector's interest is enshrined in the protection of their market shares their actions supported public objectives to prevent health hazards associated with use of untested and unregistered pesticides.

Legislation Framework and Registration System

There has been no changes in the pesticide legislation framework which is enshrined in the Fertilizer, Farm Feed and Remedies Act (Chapter 111) of 1952 (GOR, 1952). This Act which is administered by the Ministry of Lands and Agriculture, prohibits the importation, sale or distribution of pesticides without proper registration. All pesticides are registered in terms of the 1977 regulation which has also not changed since the inception of the reform program. Registered pesticides are classified into group II and III of the Hazardous

Substances and Articles (Chapter 322) of 1972, regulations of 1981 and 1985 administered by the Ministry of Health and Child Welfare.

During the reform process, the pesticide legislation framework and registration system, did not require any amendment because they adequately spell out registration procedures, storage, distribution, labeling, marketing and safety requirements. However, the enforcement agent, the Plant Protection and Research Institute which falls under the Department of Research and Specialist Services, had difficulties in coping with the increasing demands for testing new pesticide products and policing of the registration system.

10.3.3 Safety measures and international conventions

Despite their obvious advantages, if handled, stored and used incorrectly, pesticides can be poisonous to animals and human beings. While the registration system clearly spells out the requirements for meeting human and environmental safety, their effectiveness depends on the conduct of stakeholders including the state, local formulators, distributors and farmers. The role of each of these organizations is important for effective policing and overcoming of a number of potential problems associated with improper handling, storage and use of pesticides.

Role of the state

In an effort to meet safety requirements, Zimbabwe Government has put a number of monitoring mechanisms to enforce the regulations and to comply with the International Code of Conduct on the distribution and use of pesticides. The code addresses the need for cooperative efforts between pesticide exporting and importing governments to promote practices which ensure efficient and safe use while minimizing possibilities of dumping, accidental poisoning and environmental pollution (FAO, 1990).

Zimbabwe is party to the Prior Informed Consent (PIC), a system which requires that pesticides that are banned or severely restricted for health or environmental reasons are not exported into Zimbabwe without informing the registrar of pesticides with the Plant Protection and Research Institute. Compliance on restricted or banned pesticides and industrial chemicals including Chlordimeform, Chlordane, Crocidolite, DDT, Demephion, Dimefox, Endrin, E.P.N. HCH (mixed isomers), Heptachlor, Mercury Compounds, PCB, PCTs, Phorate, Schradan, Sodium Fluoroacete, Sulphotep, TEPP and TRIS has been encouraging.

However, difficulties have been experienced in the case of methyl bromide whose use has been restricted because of its odorless, tasteless, volatility and toxic nature. Methyl bromide was listed as ozone depleting pesticide with an ODP of 0.7 by the fourth meeting of the Montreal Protocol in 1992 (SCHONFIELD et al., 1994). Its presence cannot be dictated unless it is mixed with a warning agent called chloropicrin or through use of detecting equipment which are very costly. Since neither chloropicrin nor detecting equipment are widely used in Zimbabwe, it is often difficult for farmers and nearby residents to tell when methyl bromide is being used. Importing countries such as Taiwan and EEC require that methyl bromide treated agricultural produce are free of chloropicrin residues (SCHONFIELD et al., 1994). The United States of America also forbids the importation of commodities treated with methyl bromide mixed with chloropicrin because of tainting and residues on agricultural commodities.

Annually, Zimbabwe uses between 600 and 800 tons of methyl bromide for soil fumigation in tobacco crop and cut-flowers, grain storage, quarantine and pre-treatment of export commodities. The key users of methyl bromide are concerned about its ban because;

i) doubts exist on its ozone depleting extent which they estimate at 0.3 as opposed to 0.7 cited by Montreal Protocol,

ii) its adverse effects cannot be meaningfully minimized by restricting or banning agricultural uses because bulk of methyl bromide is naturally produced,

iii) half life of methyl bromide in the atmosphere is very short and its impact on the ozone layer is therefore small,

iv) its ban without appropriate alternatives will seriously undermine the competitiveness of Zimbabwe tobacco and horticultural crops and maize storage system.

Tobacco farmers are increasingly using repaired plastic covers for methyl bromide soil fumigation in an effort to contain escalating costs. This has been increasing the risks of exposing workers to methyl bromide through unrepaired holes. However, there are no reported incidences of methyl bromide poisoning related to careless storage or inadequate provision of protective clothing and use of trained workers in an effort to cut costs due to financial constraints caused by the reforms. The real concern over the excessive use of methyl bromide in soil fumigation in tobacco production, lies in the fact that its application follow preset or routine schedules rather than meeting assessed requirements.

Role of formulators, suppliers and retailers.

In 1996, CHITEMERE reported that significant inhibition of plasma and red blood cells cholinesterase had been recorded in factory workers exposed to an average of 0.7 mg per cubic liter of pesticide over a period of eight months.

However, pesticide formulators and suppliers are increasingly cooperating in financing pesticide safety awareness to minimize health risks (ACIA, 1994). ACIA members are complying with the regulations which requires them to put warning symbols on all pesticide labels. A significant number of charts depicting four classes of warning symbols in triangle color coding namely green, amber, red and purple where distributed through institutions such as AGRITEX, rural based shops, rural health centers and Farmer Unions. It is also reported that local formulators are taking measures to reduce exposure of workers to pesticides by strict monitoring of regulations which prohibits smoking and eating in factories and improving hygiene and basic worker education programs (MATCHABA, 1996).

Role of farmers

There is no evidence to suggest deteriorating health and increasing environmental hazards, particularly among farm workers due to the hardships caused by the reform program. The booklet distributed by ACIA has greatly improved awareness on the need to guard against careless handling and misuse of pesticides at farm level to avoid poisoning through skin and eye contact, inhalation, ingestion and pollution of the environment.

Large scale commercial farmers (LSCF) are fairly informed and aware of the importance of not spilling pesticides into water ponds, dams, wells, rivers, sewage systems, cultivated lands with crops, uncultivated lands supporting wild plants and animals. They find it important to maintain a tradition of ensuring that labor applying pesticides use appropriate protective clothing such as overalls, rubber gloves, face masks or goggles, head covers, rubber boots and aprons even under hardships caused by the reforms. A significant number of farmers continue to fence off and label pesticide disposing sites with warning signs. There has been noticeable acceptance by farmers to burn, crush, puncture and bury empty containers to prevent them from being used for storing water or food (ACIA, 1994). Their smallholder farm counterparts have difficulties in complying with safety requirements especially storage due to lack of proper facilities. They sometimes use empty pesticide containers for domestic purposes. However, such incidence remain low because normally pesticides are bought in small containers.

10.4 Changes in supply and demand of pesticides

Table 10-1 shows trends in various pesticide quantities used between 1988 and 1997. While the quantities for all pesticides were fairly constant between 1991 and 1994, they increased significantly between 1995 and 1997. The values of pesticides shown in Table 10-2 also follow a similar trend.

The time lag in changes in pesticide quantities and values from the onset of the reform program in 1991 to 1994 when pesticides were placed on open general import license is consistent with the infrastructure, testing and registration requirements of the pesticide industry. Effective supply from new market entrants had a three year time lag because the regulations require that new products be tested for three consecutive seasons before they can be registered and marketed commercially. It also represent a phase of upgrading facilities by existing companies as they gear themselves to meet new challenges from newly established companies and meeting health and environmental safety requirements of Food and Agricultural Organization and World Health Organization.

Table 10-1: Quantity of pesticide product sales 1988-1997 ('000 kg)

	Year									
Pesticides	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**
Insecticides	2641	2586	3075	3382	3551	3374	3205	5978	6365	6345
Herbicides	924	876	1037	1140	1197	1138	1081	2150	2155	2195
Fungicides	416	410	450	495	520	494	494	645	678	768
Others	470	363	536	590	620	589	559	565	668	685
Rodenticides	25	28	83	91	95	91	86	74	84	92
Plant growth Regulators	445	335	454	488	524	498	473	472	478	505
Total	**4451**	**4235**	**5098**	**5607**	**5888**	**5595**	**5339**	**9338**	**9866**	**9993**

Source: Agricultural Chemical Industry Association, various years

Table 10-2: Value of pesticide sales in US$ million 1987-1997

	YEAR										
Pesticide	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**
Insecticides	23.6	23.9	23.5	20.6	11.8	11.5	11.3	12.2	26.0	29.7	29.4
Herbicides	15.7	16.7	14.8	13.2	7.6	7.4	7.3	7.9	15.0	16.9	15.8
Fungicides	4.6	6.3	6.4	4.9	2.8	2.7	2.7	2.9	7.8	8.9	9.2
Others	2.8	2.9	2.8	2.4	1.3	1.3	1.3	1.4	1.6	1.8	1.9
Rodenticide	0.1	0.1	0.2	0.05	0.05	0.05	0.05	0.1	0.08	0.1	0.2
Plant growth Regulators	2.7	2.8	2.6	2.3	1.3	1.3	1.3	1.4	1.5	1.8	1.9
Total	**46.7**	**49.8**	**47.5**	**41.1**	**23.5**	**22.9**	**22.6**	**24.4**	**50.4**	**57.3**	**56.3**

Source: Agricultural Chemical Industry Association, various years

The significant increase in quantities and value of pesticides sold between 1995 and 1997 as shown in Table 10-2, suggests either increase in pesticide usage through enlarged number of suppliers or improved output from refurbished and replaced obsolete machines which were previously breaking down frequently and too costly to maintain. The training and reorientation of workers also improved productivity.

The scenario depicted in Tables 10-1 and 10-2 is also consistent with experience of other countries where stabilization measures aimed at reducing aggregate demand became effective faster than the structural strategies causing supply response lag (FAO, 1992). Such asymmetry in timeliness of effect did not only delay response on quantities of pesticides supplied but the enhancement of safety monitoring and policing measures required under liberalized environment.

Table 10-3 shows that there was a significant increase in nominal pesticide prices between 1991 and 1992. This could be attributed to price changes in source countries and transportation costs at a time when shipment of food was prioritized during and after the drought experienced in 1991/92 season. However, the prices started to go down between 1993-1997. This could be explained by;

(a) the positive structural responses and increasing competition from new players,

(b) pesticide importers realizing discounts for bulk purchases and free sourcing,

(c) the rationalization of the anomalies between import duty rates for raw materials, intermediate and finished pesticide products to promote local value adding activities and creation of employment opportunities,

(d) local pesticide traders taking advantage of eased foreign currency to procure when world prices are lowest and economies of scale in transportation by buying full container loads,

(e) the removal of import duties on capital equipment easing the replacement of out dated machinery and allowing savings on new plants and availability of spares thus reducing the frequency of losses previously caused by breakdown of old machinery and lack of adequate back up services,

(f) reduction of inefficiencies and complacence in long established suppliers which previously monopolized market shares through the foreign currency system.

The scenario emerging from Table 10-3 suggests that the reforms have promoted competition reflected in declining prices. By having access to foreign currency, pesticide producers, shifted from more expensive sources in donor countries where they were previously obliged to purchase imported machinery, spares and raw materials. In 1994, GARA reported that the chemical industry was experiencing significant improvements in product quality to meet international standards, packaging and safety standards in line with the set regulations. It has been observed that most players in the industry are focusing on identifying new and cheaper sources of pesticide and cutting costs to become competitive rather than spending resources in creating artificial barriers to new entrants in an effort to maintain monopoly profits (MOLA, 1997).

Table 10-3: Prices of selected pesticides

	US$/Unit of measurement (Kg or litre)								
Year	Pack size	1989	1990	1991	1992	1993	1995	1996	1997
HERBICIDES									
Basagran	20lt	15.9	13.1	9.7	20.6	16.3	15.2	12.0	11.2
Cotoran 80WB	20kg	13.2	12.8	7.5	17.0	17.0	17.0	14.4	11.8
Diuron 80%	25kg	9.8	8.5	6.4	12.1	11.9	12.0	11.0	11.3
Dual 720 EC	20lt	15.0	17.1	11.8	12.0	11.4	11.3	9.7	10.0
Gramoxone	5lt	8.4	8.9	13.4	11.8	10.4	8.9	7.6	7.6
INSECTICIDES									
Carbaryl 85%	25kg	7.4	6.4	7.0	11.4	12.7	9.1	8.1	8.2
Chlorpryri-phos	20lt	19.6	21.6	14.5	25.1	19.4	14.9	12.6	11.4
Dimethio-tate 40	5lt	5.9	6.5	4.7	8.3	7.0	5.2	5.4	5.6
Hostathion	5lt	21.3	19.4	15.8	30.0	26.8	17.5	23.0	24.5
Thiodan mo35	5lt	7.1	8.0	5.4	10.3	12.7	8.1	9.0	8.0
SEED DRESSING									
Inoculant	unit	0.7	0.6	0.4	0.4	0.3	0.2	1.2	0.9
Thiram	25kg	3.6	6.6	3.8	6.1	5.7	4.9	4.2	3.6
Brassicol	25kg	5.4	8.8	10.2	18.0	14.2	16.3	13.8	11.8
SOIL FUMIGANTS									
EDB ec	20lt	5.4	5.5	4.1	6.3	4.8	4.5	3.7	3.9
Methyl Bromide	680g	2.7	4.3	2.4	3.2	4.9	4.8	4.6	4.4
FUNGICIDES									
Benomyl	50kg	27.2	23.4	19.6	38.5	54.5	38.1	34.7	23.7
Bravo	20lt	8.5	8.4	4.4	16.4	13.5	12.5	11.6	11.2
Copper Oychloride	25kg	2.3	2.4	1.4	1.8	1.6	1.7	2.1	2.0

Source: Commercial Farmers Union, various years.

10.5 Conclusions

It has been noted that the need to increase agricultural productivity in Zimbabwe cannot be met without the use of indispensable agricultural pesticides. Government policy thrust to commercialize smallholder agriculture will be accompanied by significant use of pesticides inspite of efforts to introduce biological and integrated pest control systems. It has been revealed that the economic reforms have a potential to undermine human and environmental safety because of weakening monitoring, policing and enforcement systems. All stakeholders including, Government, manufacturers, traders, and users need to cooperate to effectively manage pesticide use, assess and reduce hazards which could result in their misuse. The international pressure for banning or restricting the use of effective and much needed pesticides such as methyl bromide without proper alternatives requires further examination.

The reform program saw many new players entering the pesticide industry with a doubling of the range of pesticides traded on the market. The pesticide legislative framework and regulation experienced no changes because they adequately meet both local and international code of conduct and health requirements. However, the monitoring and policing mechanisms are failing to cope with the increasing number of players in the industry. Thus pesticide testing, registration infrastructure and information systems require strengthening to meet increased stakeholder demand arising from the liberalized economic environment. The increasing financial and supervisory burden on the Plant Protection and Research Institute, requires the local suppliers and farmers to take an active role in monitoring and policing the testing and registration system to uphold human and environmental safety. In addition, the emphasis of monitoring should shift from routine factory inspection to spot checks for unregistered items in leading retail outlets. Finally farmers should be encouraged to strike a balance between good yields, cost of protecting farming operations, health crops, animals and environment.

References

ACIA (1992): Report requesting the placement of agricultural chemicals on restricted list. Agricultural Chemical Input Association, Harare.

ACIA (1994): Safe use of pesticides promotion pamphlet. Agricultural Chemical Input Association, Harare.

CFU (1987): Survey of current input costs and recent input costs increases. Commercial Farmers Union, Harare.

CFU (1989): Report on the prices of agricultural chemicals. Commercial Farmers Union, Harare.

Chitemere R. C. (1996): Pesticides and occupational safety and health in Zimbabwe. In: C.F.B. Nhachi and O.M.J. Kasilo (eds.): Pesticides in Zimbabwe - Toxicity and health implications. University of Zimbabwe Publications, Harare.

CSCZ (1997): Working document for chemical safety committee of Zimbabwe, Harare.

Gara (1994): Paper presented at a conference on beyond ESAP organized by the Confederation of Zimbabwe Industries held from 23-24 November 1994 in Kariba.

GOR (1992): Fertilizer, farm feeds and remedies act (Chapter 111). Harare.

GOZ (1991): The economic structural adjustment programme document. Harare.

FAO (1990): International code of conduct on the distribution and use of pesticides (Amended Version). Food and Agriculture Organization of the United Nations, Rome.

FAO/UNEP (1991): Operation of prior informed consent, Procedure for banned or severely restricted chemicals in international trade. Rome/Geneva.

FAO (1992): The impact of structural adjustment on the use of agricultural inputs in Africa: the case of fertilizer: A paper presented at a seminar on fertilizer strategies for Sub-Saharan Africa.

Matchaba, R.B.Z. (1996): Organophosphate exposure in pesticide formulating and packaging factories in Zimbabwe. In: C.F.B. Nhachi and O.M.J. Kasilo (eds.): Pesticides in Zimbabwe - Toxicity and health implications. University of Zimbabwe Publications, Harare. pp 51-62.

MOLA (1997): Ministry of Lands and Agriculture Report on Pesticide Industry. Harare.

Mudimu, G.D., Chigume, S. and Chikanda, M. (1995): Pesticide use and policies in Zimbabwe: Current perspectives and emerging issues for research. Pesticide Policy Publication Series No.2, University of Hannover.

Schonfield, A. , L. Wamukanya. and S. Glendening (1994): Methyl bromide use and alternatives in Sub-Saharan Africa. Pesticide Action Network North America, San Francisco.

Sithole, G (1991): Report on the review of Allocation of Foreign Currency to the Agricultural Chemical Sector in Zimbabwe. Harare.

Sithole, S.Z and G.P Chikwenhere (1993): Integrated pest management in Zimbabwe. A paper presented at the IPM implementation workshop for East/ Central/ Southern Africa.

Tsododo, G (1997): A paper on the safe use of chemicals in agriculture presented at an International Program on Chemical Safety (IPCS) workshop held in Zambia in November 1997.

ZTA (1995): The Zimbabwe Tobacco Association letter to the Ministry of Lands and Agriculture dated 25 April 1995. Harare.

11 Methodological Aspects in Benefit Assessment of Pesticides

Hermann Waibel[1]

Abstract

The existence of externalities caused by pesticide use are a major reason for market failure. Therefore, social net benefit is lower than profitability at the individual use level is indicating. That results in a deviation between private and social optimum of pesticide use levels. If governments or NGOs do not interfere in the pesticide market, externalities will not be internalized. Besides the efficiency loss, overuse results in additional costs for induced investment in risk reduction and damage prevention measures.

Overestimation of benefits at the farm level occurs under the prevailing information environment. Information on the magnitude and risk of crop loss is rarely available since pesticide use patterns contributed to neglecting on-farm observation. Pest-predator relationships and its influence on pesticide productivity can not yet sufficiently be assessed which hampers the application of production function approaches. Intertemporal dependency, i.e. the „chemical spiral“ have not yet been taken into account.

The methodological flaws of conventional economic analysis tend to overestimate the benefit which society gains from the use of pesticides. Benefits of pesticide use must be measured in terms of their contribution to increased productivity of food production, i.e. lowering its average costs. The correct reference system for benefit assessment of pesticide use is the optimized crop management strategy taking into account all available non-chemical options. In an open economy framework distortions of prices, misperceptions of the risks of crop loss and asymmetric levels of information have to be eliminated.

11.1 Introduction

Since several decades pesticides are used as the main method to control pests. On the one hand this was the consequence of changes in agricultural systems. The introduction of intensive monoculture with high yielding varieties

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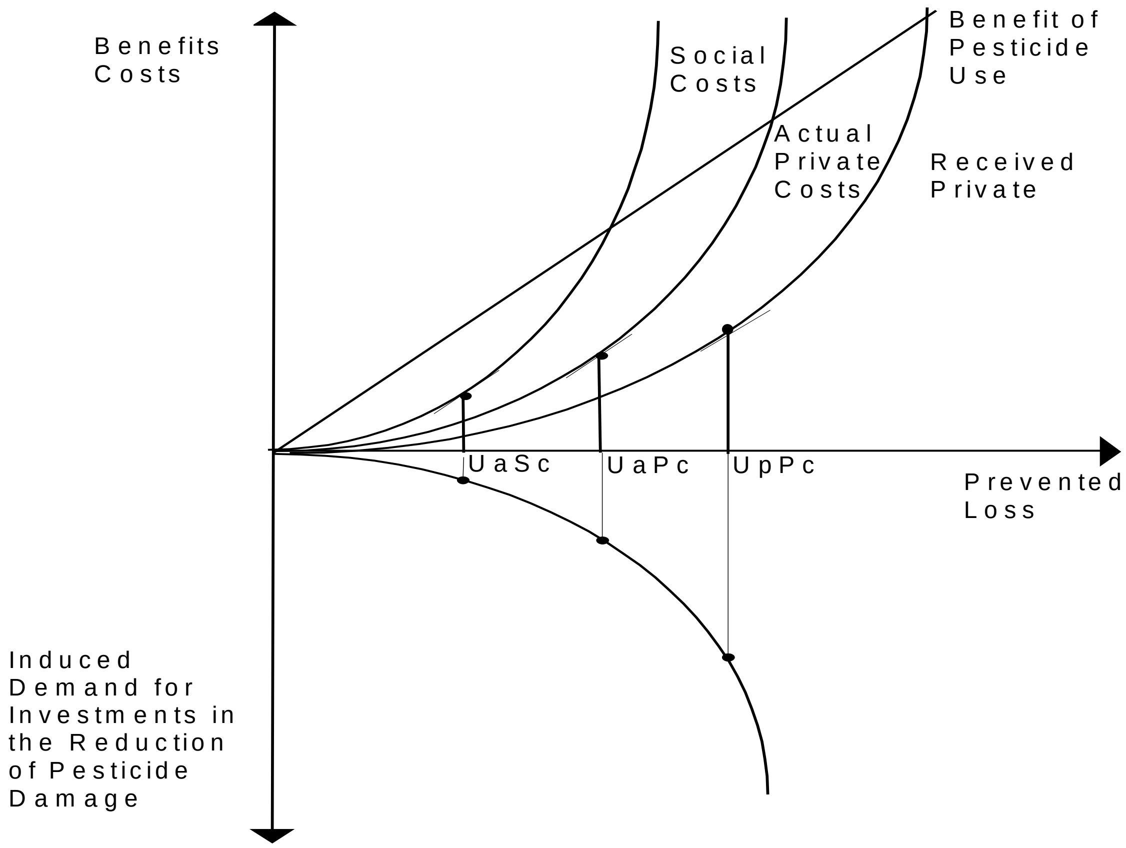
and high use rates of fertilizer made adoption of pesticides a cost-effective choice. At a first glance the benefit of following this technological path seemed obvious. On the other hand pesticides themselves have induced changes in agricultural and ecosystems with such negative consequences like pest resistance to pesticides, the destruction of beneficial organisms and pesticide residues in food and water. These "externalities" have affected the economics of pesticide use and are becoming increasingly of public concern. In response to these problems, governments established legal measures aiming at regulating the use of pesticides and mitigating negative side-effects. The overall approach is to emphasize risk reduction measures through various government activities. These investments are generally believed to be justified considering the assumed benefit to society generated by a pesticide-based technology path.

This paper deals with some methodological aspects of benefit assessment for pesticides. It is argued that the methodological flaws of conventional economic analysis tend to overestimate the benefit society gains from the use of pesticides. Section 11.2 introduces the economic concept of private and social optimum of pesticide use, while section 3 identifies the specific difficulties in benefit assessment. In the last section summary, conclusions and an outlook are presented.

11.2 Theoretical background

A general conceptual framework for benefit assessment of pesticides has to be derived from social welfare theory and must be applicable in a cost-benefit analysis. This implies that not only private decision making factors are considered, but also effects of individual management decisions on the society and the ecosystem at large has to be included (see Figure 11-1).

Figure 11-1: Optimal level of pesticide use and induced investments



Source: WAIBEL (1994)

The criterion for the farmer is to maximize expected net returns. Gross return from applying pesticides is equal to prevented crop loss in monetary terms. Costs are referred to as the amount of farm resources used for every unit of crop loss prevented. The farmer's level of pesticide use is therefore denoted with UpPc. This level depends on the farmer's subjective assessment of crop loss, the effectiveness of his control method and the costs which he perceives (perceived private costs). This may well lead to an overestimation of the returns as explained above and to an underestimation of costs if, for example, actual health hazards are not fully recognized (which are included in the actual private cost curve). If perfect information on the above mentioned variables were available, the optimal level of pesticide use would be reduced to UaPc and increase his net returns as denoted in the distance between the cost and the benefit curve. In this case the two private cost curves are identical because perfect information is assumed.

The criterion for the society as a whole on deciding how much pesticide to apply is to maximize net social benefit. This differs from the private optimum because pesticides cause external effects, e.g. through the contamination of ground water or food, which are not taken into account by the farmer. When these negative externalities are included, the cost curve shifts upwards (social cost curve) and further reduces the optimal level of pesticide use to UaSc.

If governments or NGOs do not interfere in the pesticide market, adequate information on crop loss will not be provided and externalities will not be internalized or will continue to exist until the indigenous learning curve of farmers has advanced. However, the learning curve of farmers as regards making sound pest management decisions may be rather flat because of the discouraging effect pesticides have on farmer's desire to experiment, e.g. to leave unsprayed plots for comparison is a rather rare practice, and because of the difficulty to separate the influence of pests on yield as compared to other factors. As a consequence, the level of pesticide use is likely to be above the social optimum.

The resulting overuse of pesticides causes additional costs, because potential and actual damage caused by pesticides leads to an increased need for government activities, which aim at monitoring the implementation of rules and regulations as well as at reducing the environmental and health damage caused by pesticides. Examples of such activities are the establishment of pesticide residue laboratories, residue monitoring programs and training programs on the safe use of pesticides. There is no doubt that such activities, mostly requiring public funds, are necessary in principle. However, the extent of these activities must be decided simultaneously with the level of pesticide use, or else overinvestment is likely to occur. If activities in pesticide damage mitigation measures come up to the current level of pesticide use, public funds are likely to be wasted. If pesticide use would be at a socially optimal level, the induced demand for such activities would be lower. This is shown by the lower panel of Figure 11-1 (WAIBEL, 1994).

It must be pointed out that the framework does not suggest to exactly determine an optimal level of pesticide use but is meant to guide in judging the pesticide situation in a country as being above or below the social optimum. For example, several countries in Europe have identified their use level as being too high, i.e. above their perceived social optimum and have therefore implemented pesticide use reduction plans. Furthermore, several studies found that even the private optimum is exceeded in some situations because farmers overestimate benefits and underestimate costs.

11.3 Methodological aspects of benefit assessment of pesticides

There are a number of problems in benefit estimation of pesticides as mentioned by OSKAM (1994). Firstly, the limitations of using primal approaches is due to the general difficulty of specifying a production function which is really based on cause and effect. Pesticide applications per se do not increase yields, they may reduce yield loss in case there is pest, if the right pesticide is used at the right time and at the right dose. In addition, there is the problem of measuring units of pesticide inputs. The multitude of pesticide products and their different formulations complicate the use of unitary quantitative measures. The use of bio-economic optimization models on the other hand require detailed information of the pest-crop-control complex. In both approaches an assumption must be made as regards the economic efficiency of current use levels. There are many reasons to assume that inefficiency exists.

Another aspect, less frequently mentioned when measuring benefits of pesticides is the reference system being used. Biological scientists talk of the chemical spiral, which is just another expression for dependency on pesticides. Hence, productivity of pesticides at a given point in time is the result of human interference into the ecosystem made in the past. Therefore, the usual „with and without“ comparison is likely to overestimate pesticide benefits as there is a cost of getting out of this spiral. These costs may occur in a more fragile agro-ecosystem which lowers the economic advantage of non-chemical options relying on the self-regulatory capacity of the ecosystem.

In addition to the methodology of benefit assessment, there is the question of defining benefits. The framework outlined above demonstrates that one has to be careful in identifying costs and benefits. Quite often non-economists consider non-market/social effects of pesticides as benefits. However, such effects do not reflect a free market situation but are an expression of political priorities. Taking a global perspective, benefits of pesticide use must be measured in terms of their contribution to increased productivity of food production, i.e. lowering its average costs. Based on this open economy concept, the following benefits can be identified :

- the impact on production in terms of the reduction in crop loss
- the reduction of the risk of sudden drops in production, i.e. reducing the variance in yields
- higher commodity prices related to product quality

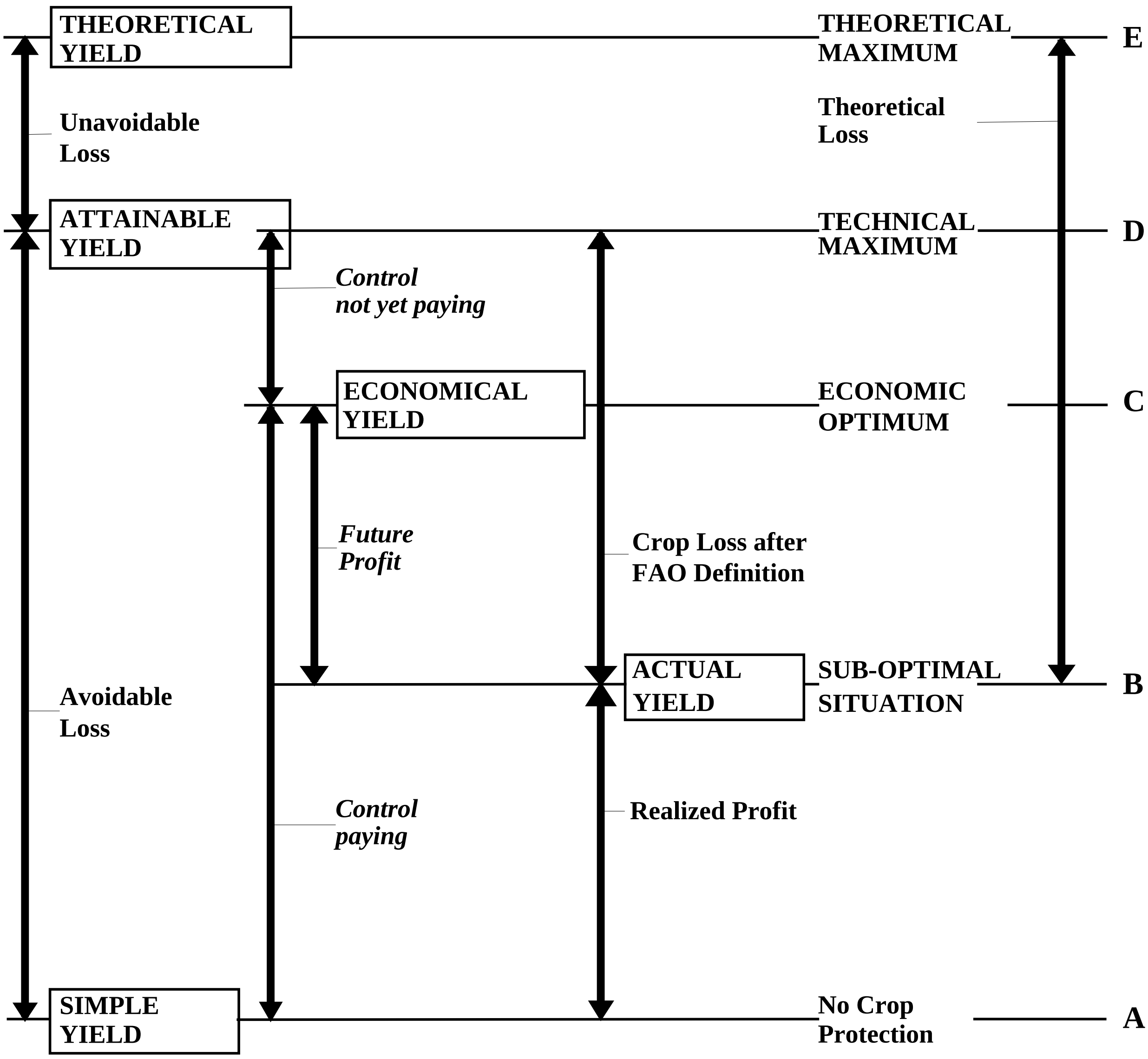
- reduced production costs related to the labor-saving effects of herbicide use
- decrease in the costs of soil conservation (soil erosion) through a substitution of tillage by herbicides

The most obvious benefit of pesticide use is seen in the reduction of crop loss. Crop loss is one of the major factors influencing pest management decisions on all levels. Perceptions of crop loss differ widely between farmers, policy makers, administrators and researchers. Their various perceptions of crop loss based on different viewpoints, information, methodology, interpretation and objectives may explain the current design of pesticide policies and pesticide use levels.

A good illustration of the pest control specialist's viewpoint of crop loss (ZADOKS and SCHEIN, 1979) is given in Figure 11-2. Here different levels of yield are used as a reference point in determining crop loss. Level A represents the situation where no control method is taking place. In this situation the yield is called the simple yield. The difference between the theoretical yield (E) and the attainable yield (D) results in the unavoidable loss. The attainable yield is the yield which can be reached with the currently available technology. The technical maximum (D) differs from the economic optimum (C) through uneconomic control costs. The difference between C and D exists because the economic optimum or the economic yield (C) is not only influenced by the currently available technology, but also through product and factor prices and production costs. Between C and D control is not yet paying.

Global crop loss estimates are often used to identify the difference between actual yield and technical maximum yield. For example, OERKE et al. (1994) calculated global crop loss in rice to reach 54% of the potential yield. Without any use of pesticides, this loss is estimated to reach 83.2%. On the other hand, when applying control methods beyond the economic optimum, costs exceed the benefits in terms of avoided crop loss. Control is only paying between situation A and C. Due to non-optimal control methods, the actual yield (B) may differ from the economically optimal yield. In the so-called „FAO definition“ (Figure 11-2) crop loss is calculated by comparing the no-crop-protection situation (A) with the technical maximum level (D), which leaves the economic view of the action without consideration.

Figure 11-2: Theoretical determination of yield and loss levels



Source: ZADOKS and SCHEIN, 1979

In the quantification of crop loss, generally trial data, mostly derived from research stations, are used. Usually a comparison is made between a no spray or no pesticide treatment and maximum protection treatment, where the calculated yield difference is called crop loss. This crop loss definition completely ignores economic realities on three levels. Firstly, maximum protection is unlikely to result in a yield which is economically optimal and secondly, a „no pesticide“ treatment is likely to trigger considerable changes in agronomic practices in order to become an optimal adjustment strategy under a „without pesticide“ situation. By just looking at „spray“ versus „no spray“ strategies unrealistic alternatives are being compared. Thirdly, pest pressure in experiment stations is likely to be higher than under field conditions because of continuous and off-season cropping.

Studies in rice in Asia have shown that intensive production systems could be managed with reduced pesticide levels. Conventional crop loss studies due to insect damage show a large impact of insect pests on the attainable yield. Results of studies differ depending on objectives and methodology of the trial (TENG, 1990). An economic study conducted by ROLA and PINGALI (1993) in the Philippines, however, found that insecticide use in rice turns out to be uneconomical in most cases. This underlines the importance of defining crop loss in economic terms. Economic crop loss must be defined as that level of yield loss and consequently pest population levels where cost of food production reaches its minimum. This is determined by the costs of control and the monetary value of crop loss. An economic yield therefore can be defined as the maximum yield level where methods to reduce yield loss can be economically justified - in other words, the yield where the marginal costs of pest control equals the marginal monetary value of crop loss. It is important for the process of introducing economic concepts in pest management decision making that economists effectively communicate this concept to plant protection specialists in order to make them to re-think their crop loss definitions.

A factor that has to be taken into account when identifying benefits based on loss assessment refers to the status and the development of the ecosystem within which beneficial insects can serve as an important natural control factor. In fact, as pesticides unintentionally kill these organisms, benefit assessment receives a dynamic dimension. Lowering beneficial populations increases the likelihood and the numbers of pests and therefore increases the potential crop loss. Results of crop loss and consequently benefit assessment in a given cropping period becomes a function of the actions taken in prior periods. In a study on pesticide use in the German agricultural sector a positive intertemporal relationship of pesticide use in consecutive periods could be shown, i.e. pesticide use in period t partly explained pesticide use in period t+n (WAIBEL and FLEISCHER, 1997). As a conclusion, in order to take care of the dynamic nature of the pest-pesticide interaction, crop loss assessment can only be meaningfully interpreted if the state of the ecosystem is known. In fact a growing dependence on pesticides has to be considered as costs not as benefit.

As mentioned above pest management decision makers especially those belonging to the group with an interest in selling pesticides often tend to treat other effects as benefits. Among the frequently mentioned effects are :

- improved food security
- lower food prices and/or a more diversified diet
- decreased encroachment of agriculture in wilderness areas
- more leisure time when using herbicides instead of mechanical or hand weeding.

Such effects have to be attributed to political priorities in relation to trade policy, income distribution policy, employment policy and other national priorities. Their value cannot be derived from market prices and are thus to be discarded in an economic framework. These effects have to be dealt within the framework of a multi-criteria analysis (MCA) where criteria and weighting factors have to be determined by a participatory process of an institutionalized social discourse. Additional pesticide use levels stimulated by political priorities cannot be considered as benefits but must be subjected to cost-effectiveness analysis.

11.4 Conclusions

In benefit assessment of pesticide use the following methodological specifications have to be dealt with:

a) Crop loss assessment as a basis for benefit assessment has to be done by taking into consideration the full range of pest control alternatives including non-chemical measures.

b) Global crop loss assessments are not adaptable to local situations and should therefore not be the only perception for possible gains of a pesticide-oriented national crop protection policy.

c) The correct reference system for benefit assessment of pesticide use is the optimized crop management strategy taking into account all available non-chemical options. In an open economy framework, as proposed in this paper, distortions of prices, misperceptions of the risks of crop loss and asymmetric levels of information have to be eliminated.

d) Benefit assessment has to recognize the intertemporal pest-pesticide interaction in order to avoid the measurement of artificially induced benefits.

As shown by empirical studies and the methodological flaws identified in the current way benefits of pesticide use is assessed, it can be assumed that there is a strong tendency to overestimate benefits. It therefore is necessary to undertake a thorough re-evaluation of the benefits of pesticide use for all major crops. Such analysis must clearly distinguish between economic benefits and other for political and social reasons "desired" effects associated with the use of pesticides in the context of a defined optimal level of use. It is equally important that regulatory decisions and the procedure of risk-benefit assessment established by natural scientists is subjected to economic criteria based on welfare theory. Economists therefore need to improve their communication skills in order to make plant protection specialists experience economic realities following a participatory process.

References

Oerke, E.C, H.W. Dehne, F. Schönbeck and A. Weber (1994): Crop production and crop protection - Estimated loss in major food and cash crops. Elsevier, Amsterdam, Netherlands.

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

Teng, P.S. (1990): Crop loss assessment: A review of representative approaches and current technology. In: IRRI (ed.), Crop loss assessment in rice, International Rice Research Institute, Los Banos, Philippines.

Waibel, H. (1994): Towards a framework for economic evaluation of pesticide policies. In: S. Agne, G. Fleischer, H. Waibel (eds.), Proceedings of the Göttingen workshop on pesticide policies. Institute for Agricultural Economics, Göttingen University, Germany.

Waibel, H., G. Fleischer (1997): Incorporating user costs into the assessment of pesticide productivity. In: A.J. Oskam, R.A.N. Vijftigschild (eds.), Proceedings of the Wageningen Workshop on Pesticides, EU Concerted Action on "Policy measures to control environmental impacts from agriculture", 24 - 27 August 1995, Wageningen Agricultural University, p. 136-151.

Zadoks, J.C. and S. Schein (1979): Epidemiology and plant disease management. Oxford University Press.

12 The Role of Economic Analysis of Pesticide Use and Policy – Experiences from Country Case Studies

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Abstract

Growing concern on rising pesticide use levels in many countries leads to questions about maintaining agricultural productivity and the sustainability of land use. Crop intensification strategies and governments' subsidies are further promoting increase of chemical pesticide use. The occurrence of negative externalities e.g. occupational health effects and damage to natural resources, leads to the problem of approaching the social optimum of agricultural input use.

Case studies on pesticide use and related policies play a significant role in highlighting existing policy patterns. A common framework comprising the analysis of economic, institutional and political factors of influencing pesticide use is applied. The theoretical analysis of the determinants of pesticide use and policies suggests that, both, price and non-price factors distort chemical input use from its social optimum. Country studies aim at a comprehensive analysis and evaluation of the importance of these factors in different regions of the world.

Indirect price subsidies such as tax and import duty exemptions are frequently to be found. As results from Costa Rica, Thailand and Côte d'Ivoire show, institutional factors are dominant in crop protection and pesticide policy such as priority setting in education, research and extension. The constraints in the availability of information at the farmer's level also lead to an advantage of chemical input use over its substitutes and alternatives. External costs are not considered as a relevant criterion for determining the optimal use level.

A ranking of the relative importance of the different factors has been elaborated in workshops among crop protection policy experts, decision-makers and interest group representatives. It is envisaged to use study results as an entry point for considering economic aspects in plant protection policy. Economic analysis of benefits and costs, based on the framework of welfare

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economics, should be a key element in formulating socially efficient policies and preventing misguided government investments.

12.1 Introduction

Chemical pesticide use in developing countries has grown substantially in the last decades. The so-called Green Revolution technological package of high-yielding varieties and mineral fertilizer demands the use of chemical pesticides to secure the full achievement of the yield potential. Both, national governments and bi- and multilateral donor agencies promoted pesticide use in order to achieve national food security and match the production goals of agricultural export commodities. In this context, chemical pesticide use was seen as an indispensable tool for modernization of agricultural production.

Alternative crop protection methods which are more environmentally benign like integrated pest management (IPM) have been developed to overcome the dependency of cropping systems on chemical pesticides. However, the diffusion of IPM is severely impeded because in many developing countries pesticide use is subsidized and favored against non-chemical pest control measures.

The aim of the present paper is to outline the rationale and the importance of country studies as a step towards economic analysis and decision support in agricultural and resource policy. The methodological approach chosen relies heavily on multi- and interdisciplinary work from the fields of natural science, toxicology, political science and economics. The framework for policy analysis has been elaborated during an international workshop of economists and policy specialists (AGNE et al., 1994). Results of its application to case studies are presented. Conclusions for policy decisions as well as for further analysis will be drawn.

12.2 Pesticide use trends and associated problems

World sales of chemical pesticides are constantly rising. They have reached about US$ 31 billion. It is estimated that about one third of the world sales of chemical pesticides is used in developing countries, thereof 16% in Asia, 13% in Latin America, and each 2% in Africa and in the eastern transformation countries.

Forecasts of market research companies suggest a further increase of sales in major regions of the developing world. Pesticide use in industrialized countries has stabilized due to internal adjustments of agricultural policies, while major developing countries in Asia and Latin America have high predicted growth rates.

Africa faced high growth rates up to the end of the eighties before the debt crisis limited the availability of foreign exchange for imports and changes in agricultural policies were enforced (ADESINA, 1994). Although overall pesticide use in Sub-Saharan Africa declined, certain usages connected with high levels of intensity in cash and export crops remain high and give reason for concern (SZMEDRA, 1994; MATTESON and MELTZER, 1995).

Crop intensification strategies relying exclusively on chemical pesticide use have been questioned for a number of reasons. Firstly, occupational health hazards occurred that affected farmers and laborers as well as their families. The World Health Organisation estimated the number of occupational poisoning cases to 1 million with 20,000 deaths per year (WHO, 1990).

Secondly, damage to natural resources became more and more obvious which is placing increasing costs to agriculture and other sectors of the national economy. Pesticide residues contaminate drinking water and food and endanger natural biodiversity.

Thirdly, overuse of pesticides endangers agricultural production in the long run. The case of brown plant hopper in rice has proven that indiscriminate and prophylactic insecticide use destroys the natural self-regulation by elimination of natural predators. It causes severe outbreaks of secondary pests thus provoking ever-increasing pesticide use (HEONG et al., 1995). Research in highly-intensive vegetable systems showed that dependency on chemical protection causes resource costs (WAIBEL and SETBOORNSARNG, 1993). Agro-ecosystems deteriorate and may in the long run collapse.

Fourth, public opinion and consumer demand in industrialized countries became increasingly aware of environmental problems caused by intensive farming. Since exports of agricultural commodities from developing countries are not independent from demand changes, regulatory pressure in order to cope with food residue limits arise.

Although some of the negative side-effects prompted by chemical pesticide use have been documented, a comprehensive appraisal is frequently missing, especially on the level of the individual countries. Conclusions for policy intervention can only be made when the driving forces of pesticide use and opportunities and constraints of influencing use trends are known.

12.3 Theoretical concept of pesticide policy studies

Farmer's decision-making on the type and amount of pesticide use depends on several considerations, i.e. type of pest, expected crop loss, price ratio of output and input prices, risk attitude and availability of input resources. However, subsidies and other institutional factors distorting use levels may contribute to pesticide usage that exceeds the optimum from the society's point of view. At the same time, alternatives in pest management are under-utilized which leads to productivity loss for the national economy.

Economic analysis of benefits and costs of pesticide use depends highly on co-operative work with natural scientists, agronomists and toxicologists. The exact determination of the socially optimal level may not always be feasible due to uncertainty about the magnitude of effects and lack of data (OSKAM, 1994). However, it appears particularly useful to determine the extent of the deviation of different private and social optima and the relative importance of distorting factors (WAIBEL, 1994). Here, the integration of economic and policy analysis is particularly useful.

In analyzing effects that contribute to the distortion of pesticide use from its socially optimal level, several groups of subsidizing and promoting factors can be distinguished (see Table 12-1). The farm-gate price of pesticides can be lowered by direct transfer payments to pesticide industries, retailers or by government distribution. These factors can be classified as obvious price factors. The decision-making of the actual pesticide user whether to apply pesticides or to use alternative crop protection methods is influenced also by some other reasons which are acting indirectly and frequently hidden. Biases towards chemical solutions in institutional settings, such as the agricultural education system, priorities in the research programs and organization of the extension service, have an important influence on the generation and the direction of technical progress and its implementation on the field level. With regard to human resources the type and level of information on different crop protection strategies is decisive for the over- and misuse of chemicals of pesticides as well as the under-utilization of non-chemical alternatives. Inappropriate government intervention in case of occurrence of external effects can play also an important role on keeping pesticide use levels high.

Table 12-1: Factors causing excessive pesticide use

	Price Factors	Non-Price Factors
Obvious	**I** 1. Government sells or gives pesticides 2. Donors provide pesticides at low or no costs 3. Government refunds pesticide companies costs 4. Subsidized credit for pesticides 5. Preferential rates for tax and exchange rate	**III** 1. Misguided use of governments' activities in reducing pesticide damage 2. Governments' investments in pesticide research 3. Inadequate government research in environmentally benign pest management
Hidden	**III** 1. Plant Protection Service outbreak budget 2. Pesticide production externalities 3. Pesticide use externalities	**IV** 1. Lack of adequate procedures for - pest definition - crop loss definition 2. Lack of information on agro-ecological parameters 3. Lack of transparency in regulatory decision making 4. Curricula of agricultural education and extension 5. Dominance of pesticide industry in the market for crop protection information

Source: modified from WAIBEL (1994)

Pesticide subsidies have been first analyzed by REPETTO (1985) pointing at the very high amount of direct price support, government distribution at low or no cost for the user and the effects of exchange rate regimes in nine developing countries. A literature review of the World Bank (FARAH, 1994) used an extended framework for the identification of subsidizing factors based on research in Thailand (WAIBEL, 1990). Despite the decisive impact of structural adjustment programs (SAP) on abolishing direct price subsidies it appeared that both, hidden price factors and non-price factors play still an important role in many parts of the world. This stands in sharp contrast to the declaration of IPM as a national policy goal in many countries (FLEISCHER and WAIBEL, 1993).

In order to get country-specific information on the extent of direct and indirect subsidies, a methodological framework for country studies on pesticide policies has been elaborated (AGNE et al., 1995). The framework is based on a welfare economic approach. It aims at revealing economic, institutional and political factors that contribute to the deviation of social and private cost curves of pesticide use. A comprehensive analysis in the following areas is included:

- Characteristics of the agricultural sector, e.g. relative importance of the sector, farm size structure, dependence of the sector on external economies
- Analysis of pest problems, pest management practices and pesticide use trends
- Externalities of pesticide use (e.g. occupational health impacts, water pollution, damage to natural resources, pesticide resistance)
- Evaluation of agricultural policy, i.e. market and input price policies, trade and exchange rate policies, commodity price support measures
- Regulatory intervention, i.e. registration requirements and procedures
- Perception of pesticide use and regulation in the society, e.g. perception of crop loss by different groups of the society, perception of health and environmental risks
- Farm and crop characteristics of pesticide use, e.g. biophysical and socio-economic characteristics of farming system, crop profile, characteristics of and information level on plant protection strategies, awareness of health risks
- Economic evaluation of different pest control strategies from the viewpoint of the private user and the society.

12.4 Results on pesticide use distorting factors

The framework has been applied to case studies in Costa Rica, Thailand and Côte d'Ivoire in cooperation with local and regional organizations (AGNE, 1996; JUNGBLUTH, 1996, FLEISCHER et al., 1998). Results show an increasing trend of pesticide consumption in recent years in all three countries (see Table 12-2). This is mainly caused by general intensification of agricultural production and the shift towards crops that consume high amounts of chemical pesticide per area unit. The latter holds true especially for fruit, vegetable and plantation crops.

Table 12-2: Pesticide use level in case study countries

Country	Current use level (US$ million)	Average growth rate per year
Costa Rica	75.5 (1994)	9.8% (1990-1994)
Thailand	247 (1994)	18.8% (1992-1994)
Côte d'Ivoire	41.1 (1997)	8.1% (1994-1997)

Source: calculated from AGNE (1996), JUNGBLUTH (1996) and FLEISCHER et al. (1998)

The analysis of the driving forces of pesticide use shows that various economic and institutional mechanisms stimulate farm-level use patterns. Indirect government subsidies, i.e. by import duty and sales tax exemptions, play a major role in lowering the pesticide price to the user. Exemptions for fertilizer influence pesticide use decisions in the same direction, especially in those crops where both inputs are complementary. Increasing pesticide taxes to the normal level would lower national pesticide consumption in Costa Rica by US$ 5 million (6%) (AGNE, 1996). Additionally, the government would improve its financial position and farmers could be compensated for income losses by funding alternative crop protection technologies.

Among the effects of biases in the institutional setting, government promotion of pesticide-intensive production systems plays the most important role. Those systems are supported by priority setting in agricultural development program and hence indirectly subsidized and favored against other crops. In some crops such as cotton in Côte d'Ivoire, credit programs are bound to obligatory pesticide use. Educational and training curricula lack the adequate consideration of non-chemical crop protection strategies. Priorities and resources in extension services and in research are geared towards the adoption of chemical solutions only. Thailand has allocated funds to IPM research as well, however, its impact on pesticide use levels is small in view of the importance of the other factors.

The informational environment for the decision-making at farm level is almost exclusively dominated by chemical solutions for perceived pest problems. Farmers lack, both, adequate information on alternatives to chemical products as well as the knowledge on feasible use reduction measures such as understanding of agro-ecological principles. IPM training programs currently reach only a small number of farmers and have still a negligible impact on national consumption levels.

Some types of externalities are beginning to be recognized. Externality problems arise from occupational health problems of farmers and farm laborers. However, documented cases by the medical services of the countries do not fully reflect the actual level of poisoning since considerable underreporting is assumed. In Thailand, a case study has shown that the number of poisoning cases is likely to be 13 times higher than official records (JUNGBLUTH, 1996).

Contamination of the environment by pesticide residues has been proven in all three countries. In Thailand, a comparatively large survey found residues in over 90% of soil, sediment and fish samples as well as in over 50% of water samples. Contamination of water resources has been documented in Costa Rica from effluents of banana plantains and packaging stations. Samples of fish from lakes and rivers in Côte d'Ivoire show high levels of organochlorine pesticides which exceed partly the maximum residue levels for human consumption.

Thailand funds a safe use program on health risk reduction. Such programs reach only a limited number of persons and are not able to significantly reduce health damage. Mitigation of damage to human health and the environment by government investment programs generally faces the problem of violating the polluter-pays-principle. Pesticide use decisions are not affected by the expenses of e.g. programs on residue monitoring in food and water which are paid from government resources. In economic terms, an internalization of these external costs into private user's decision-making is lacking. However, most of the external costs may only be detected and assessed in the long run, such as losses to biodiversity.

An attempt for a comprehensive estimation of external costs has been made in the Thailand study, although there is a lack of information on some externalities (see Table 12-3). Taking the evaluated range, external costs are between 9 and 93% of the current market value of pesticides. This may well be an underestimation of the true costs. PIMENTEL et al. (1993) calculated a ratio of about 200% for the USA. ROLA and PINGALI (1993) came to the same figure for health costs of insecticides in rice farming of the Philippines.

Table 12-3: External costs of pesticide use in Thailand

Cost type	Method of assessment	Estimated annual costs (million Baht[1])
Human health damage	Case study on acute occupational health in citrus growing area	13.0
Resistance and resurgence of pests	Outbreak budget of plant protection service for control of rice pests and support of rice farmers	57.4
Market produce loss due to residues[2]	Market value of contaminated fruits and vegetables	5,037
Government regulation, control and extension	Budget for pesticide quality and food residue monitoring, for pesticide regulation and market control, and for research and extension of chemical control	404.4
External costs of pesticide use (range)[3]	**(excludes other externalities, e.g. water contamination, loss of wild life etc.)**	**462.8 to 5491.8**

[1] Exchange rate at the time of the survey: 1 US$ = 25.6 Baht

[2] 10% of samples in fruit and vegetables exceed maximum residue limits. Therefore, produce should be withdrawn, but regulatory control is inefficient. Therefore, other costs, e.g. chromic human health hazard may occur. More detailed research is needed in this area.

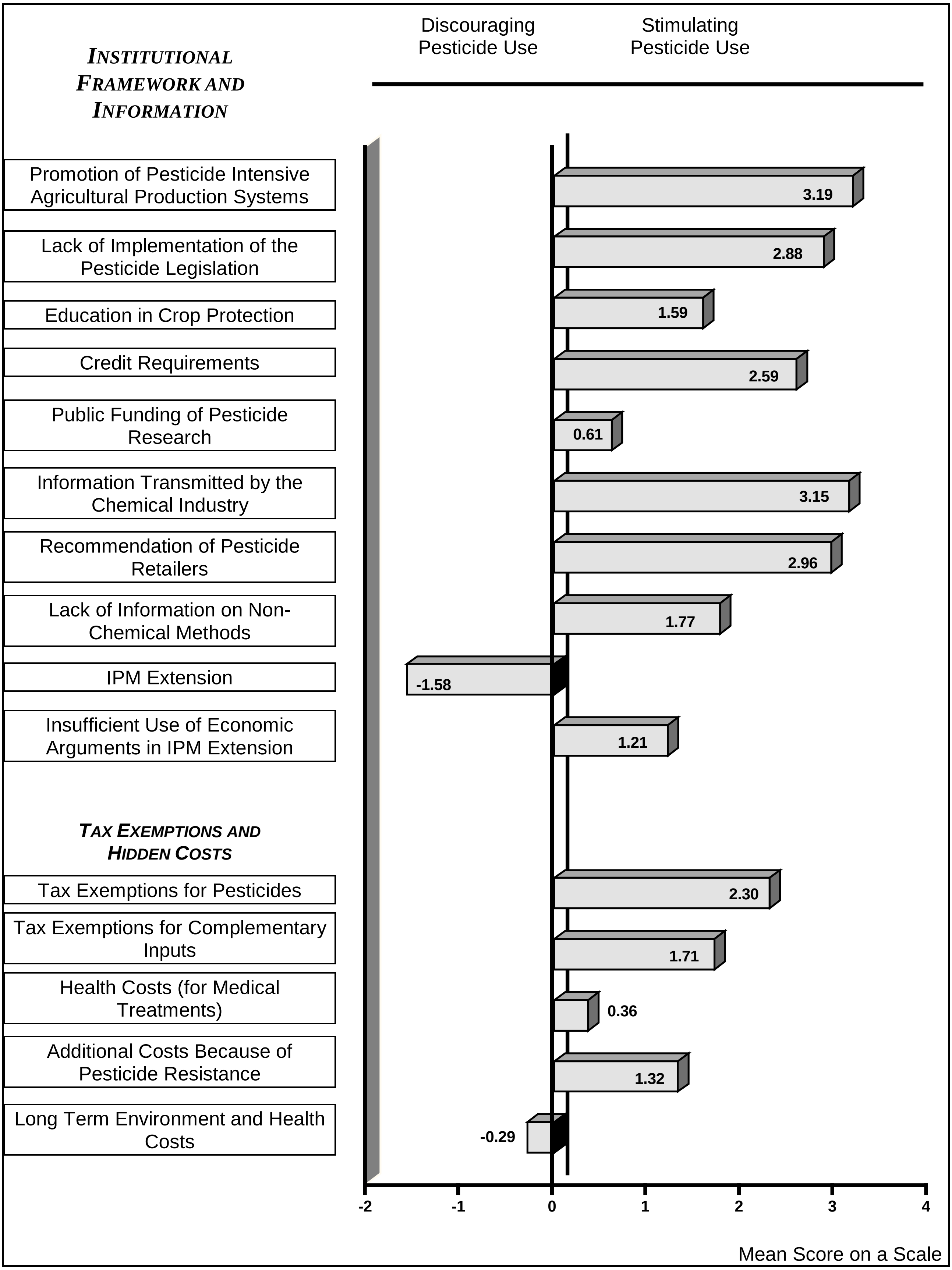
[3] lower boundary excludes the market value of contaminated produce

Source: modified from JUNGBLUTH (1996)

The impact of the different factors that subsidize and promote pesticide use were evaluated by using expert opinion. The situation analysis was discussed with representatives from government ministries and agencies in the fields of agriculture, trade and economic policy, labor, environment and human health, as well as non-governmental organizations, e.g. pesticide industry, farmers' associations and environmental groups. A common perspective on the scope of pesticide use and its externalities was reached, although different viewpoints on the extent of the problem and conceivable measures were taken.

An overall ranking of stimulating and discouraging factors of chemical pesticide use was done by the experts from the different organizations. The example of Costa Rica shows that the overwhelming majority of influencing factors act towards use levels which exceed the social optimum (see Figure 12-1). Pesticide use is too high from the society's point of view. Only a small number of measures are applied to counterbalance the effects of indirect subsidies and other promoting influences. With regard to IPM as an often cited example for future crop protection strategies, it can be concluded that a major impact on overall pesticide use levels is constrained by the large number of factors that favor chemical pesticide use.

Figure 12-1: Determinants of pesticide use and their impact (AGNE, 1996)



12.5 Steps to policy reform

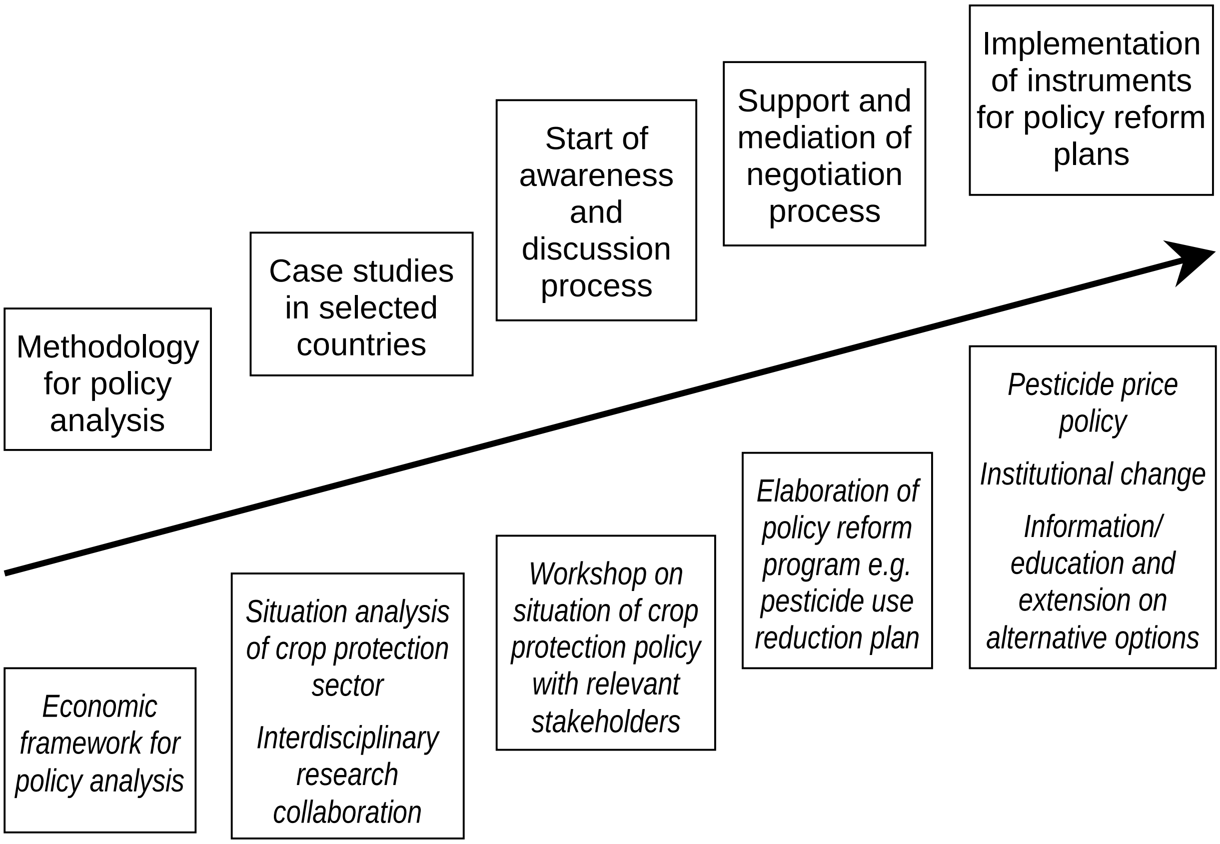
The situation analysis of the crop protection sector is a first step for establishing a common information basis. Pesticides and crop protection policy is part of the larger agricultural and environmental policy framework. Therefore, policy reform is to be achieved by a negotiation process among relevant stakeholders. This process involves several steps (see Figure 12-2) before actual policy instruments can be implemented.

Experience with policy reform workshops are available for Thailand and the Central America region. The Central American workshop explored the potential role of economic instruments in crop protection policy based on the findings of pesticide policy reports from five countries. A common understanding was reached that legislative measures should be harmonized in the region but are not sufficient for the regulation of pesticide use. The process of establishing a common market in the region demands also a harmonized approach for the withdrawal of tax exemption and for taxation of pesticides (REICHE et al., 1999).

In Thailand, a national workshop among stakeholders from all relevant government organizations and societal interest groups recommended a master plan on sustainable agriculture (POAPONGSAKORN et al., 1999). Efforts aiming at the faster introduction of IPM should be accompanied by economic instruments that reverse the favorable treatment of chemical control strategies over its potential alternatives. Since the country is known for its too liberal pesticide market a need for tightening regulatory policy was expressed, especially with regard to highly toxic products. In a comparatively advanced economic situation like Thailand, changes in the institutional environment of crop protection decisions play a major role. Workshop participants demanded the adoption of new paradigms and priorities in research, education and extension. Obligations for pesticide use in credit schemes as well as special government budgets for subsidies in outbreak situations should be abolished.

Further continuation of the policy reform process depends on the awareness of major actors as well as the relative position of the interest groups in the political process. Pesticide use reduction plans have been used in several European countries to reconcile conflicting interests and achieve a framework for the elaboration of a package of instruments (REUS et al., 1994).

Figure 12-2: Strategy of policy reform



12.6 Conclusions

Country studies play an important role in the provision of information to policy makers. The analysis of pesticide use in Costa Rica, Côte d'Ivoire and Thailand clearly demonstrates that a high number of influencing factors distorts pesticide use levels from its social optimum. Although the exact quantification of the difference between the actual private and the social costs is still lacking, the identification of the distorting factors is crucial for discussion and formulation of appropriate regulatory and economic policies.

Pesticide use and policy studies on the national level are an important element in strategies for rearranging pesticide policies to the needs of sustainable agricultural development. In this respect country studies focus, both, at analyzing of the existing situation in crop protection and pesticide use by the available data and at preparing an information base which can be used for policy formulation.

Experience from conducting policy workshops has clearly demonstrated that the situation analysis of the crop protection sector is an appropriate entrance point for awareness creation among different stakeholders. The political process on harmonizing approaches to chemical pesticide regulation can be established among different ministries and department. Typically, there exist conflicts between different ministries and agencies on the extent of the problem and suitable measures to be taken. Inter-agency committees are blocked by differing perceptions and interests. In this case, policy studies covering all aspects of the pesticide use problem as complete as possible improve the common information base and help to identify action areas of high priority.

The example of Côte d'Ivoire shows that an adaptation of the framework is needed to the situation of countries with a dualistic agricultural sector, i.e. a comparatively large sector dominated by subsistence and semi-subsistence farming systems and a small but highly productive commercial sector. Whereas in the latter pesticides are definitely used above its social optimum, causing a substantial extent of externalities, the objective for the large areas of low-intensive systems will be to avoid a situation where the entrance into the dependency on pesticide use is inevitable.

References:

Adesina, A. (1994): Pesticide use and policy in West Africa: an overview. In: S. Agne, G. Fleischer, H. Waibel (eds.), Proceedings of the Göttingen Workshop on Pesticide Policies, 28 February - 4 March 1994, Göttingen, Germany.

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 Publications No.1, University of Hannover, Germany.

Agne, S. (1996): Economic analysis of crop protection policy in Costa Rica. Pesticide Policy Project Publications No.4, University of Hannover, Germany.

Farah, J. (1994): Pesticide policies in developing countries - Do they encourage excessive pesticide use?. World Bank Technical Paper Series N° 238, Washington D.C.

Fleischer, G., H. Waibel (1993): Survey among plant protection officers during the Global IPM Conference, Bangkok, August 1993. Report to the FAO/UNEP Panel of Experts on Integrated Pest Control, Göttingen/Rome.

Heong, K.L., P.S. Teng, K. Moody (1995): Managing rice pests with less chemicals. GeoJournal, Vol.35, No.3, pp. 337-349.

Jungbluth, F. (1996): Pesticide policy in Thailand. Pesticide Policy Project Publications No.5, University of Hannover, Germany.

Matteson, P.; M. Meltzer (1995): Environmental and economic implications of agriculture trade and promotion policies in Kenya: Pest and pesticide Management. United States Agency for International Development/Winrock International. Washington/Arlington.

Mudimu, D.G., S. Chugume and M. Chikanda (1995): Pesticide use and policies in Zimbabwe - Current perspectives and emerging issues for research. Pesticide Policy Project Publications No.2, University of Hannover, Germany.

Oskam, A. (1994): Pesticides - issues at stake for economists. In: J. Michalek and C.H. Hanf (eds.), The economic consequences of a drastic reduction in pesticide use in the European Union. Revised papers of a workshop held in Tannenfelde (Schleswig-Holstein), November 13th - 14th, 1993. Kiel, pp. 81-108.

Pimentel, D., H. Acquay, M. Biltonen, P. Rice, M. Silva, J. Nelson, V. Lipner, S. Giordano, A. Horowitz und M. D´Amore (1993): Assessment of environmental and economic impacts of pesticide use. In: Pimentel, D. and H. Lehman (eds.): The Pesticide Question - Environment, Economics, and Ethics. New York, London. pp. 47-84.

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.

Reiche, C., O. Ramirez, S. Agne, H. Waibel (1999): Proceedings of the workshop on crop protection policies in Central America, 17 - 19 September 1997, Turrialba, Costa Rica (Draft paper to be published by the Instituto Interamericano de Cooperación para la Agricultura (IICA), San José, Costa Rica).

Repetto, R. (1985): Paying the price - pesticide subsidies in developing countries. World Resources Institute, Washington, D.C.

Reus, J., H. Weckseler, G. Pak (1994): Towards a future EC pesticide policy -An inventory of risks of pesticide use, possible solutions and policy instruments. Centre for Agriculture and Environment, Utrecht.

Rola, A., P. Pingali (1993): Pesticides, rice productivity, and farmers' health - An economic assessment. International Rice Research Instiute (IRRI), Los Baños, Philippines.

Szmedra, P. (1994): Pesticides and the agrichemical Industry in Sub-Saharan Africa. United States Agency for International Development/Winrock International. Washington/Arlington.

Waibel, H. (1990): Pesticide subsidies and the diffusion of IPM in rice in Southeast Asia: The case of Thailand. In: FAO Plant Protection Bulletin, Vol. 38, No. 2, pp.105-111.

Waibel, H., S. Setboonsarng (1993): Resource degradation due to chemical inputs in vegetable-based farming systems in Thailand. In: Journal of the Asian Farming Systems Association, Vol.2, No.1, pp. 107-120.

Waibel, H. (1994): Towards an economic framework of pesticide policy studies. In: Agne, S., G. Fleischer and H. Waibel (eds.): Proceedings of the Göttingen Workshop on Pesticide Policies, Göttinger Schriften zur Agrarökonomie, Vol. 66. Institute of Agricultural Economics, University of Göttingen, 1994.

WHO/UNEP (1990): Public health impact of pesticides used in agriculture. World Health Organization, Geneva.

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. & 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.

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