NEW *directions*
IN AGRI-FOOD & RURAL RESEARCH

Research Project SR9128: Survey of Pesticide Use and Evaluation of the Changes in Pesticide Risk on Agricultural Crops in Ontario

EVALUATION OF THE CHANGES IN PESTICIDE RISK

G.J. Gallivan, H. Berges and B. McGee

NEW *directions*
IN AGRI-FOOD & RURAL RESEARCH

Research Project SR9128: Survey of Pesticide Use and Evaluation of the Changes in Pesticide Risk on Agricultural Crops in Ontario

EVALUATION OF THE CHANGES IN PESTICIDE RISK

by

G.J. Gallivan[1], H. Berges[2] and B. McGee[2]

June 22, 2005

[1] 187 Cluny Street, Ottawa, ON. K1G 0J9

[2] Ontario Ministry of Agriculture and Food, 1 Stone Road West, Guelph, ON. N1G 4Y2

EXECUTIVE SUMMARY

The objective of this study was to analyse the changes in pesticide use and risk on agricultural crops in the Province in Ontario from 1973 to 2003. Pesticide risk was assessed using three scoring systems, the Environmental Impact Quotient (EIQ) (Kovach et al. 1992), the Environmental Hazard Index (Pease et al. 1996), and the Priority Substances List (PSL) score (Koniecki et al. 1997). Risk scores were calculated for 209 pesticides using publicly available data sources, with preference to the most recent assessments from regulatory agencies such as the US EPA, PMRA, California EPA and WHO. Pesticide risk was calculated by multiplying the risk scores for individual pesticides by the amount of pesticide used on each crop each year. The changes in pesticide use and risk were expressed as a percentage of the 1983 values. !983 was the baseline survey used in Food Systems 2002, a program to reduce pesticide use on agricultural crops in the Province of Ontario by 50% by the year 2002.

There was an increase in pesticide use and risk on agricultural crops from 1973 to 1983. This was associated with an increase in crop yield and yield per hectare of crop area. From 1983 to 2003, pesticide use declined 50%, while crop yield per hectare increased by 18%. From 1983 to 2003, pesticide risk declined by 52 - 60%, exceeding the reduction in pesticide use. There was decrease in pesticide risk per kg of pesticide using all three scoring systems, and a reduction in the number and amount of “high risk” pesticides used.

The reductions in pesticide use and risk were greatest on corn and tobacco, the crops with the highest pesticide use in 1983. Pesticide use on soybeans did not change significantly because of the increase in crop area, but pesticide use per ha declined by 58%. There was a 40% reduction in the risk per kg of pesticides applied to soybeans using the EHI and PSL, but a 45% increase using the EIQ. This discrepancy occurred because of differences in the ranking of the score for glyphosate, the most commonly used herbicide in 2003, relative to other herbicides. There was a reduction in pesticide use and risk on fruits and vegetables from 1983 to 2003 because of the reduced use of insecticides in 1998 and 2003, and the reduced use of fungicides in 2003. There were substantial reductions in the use of carbamate and organophosphate insecticides, and in the use of dithiocarbamate fungicides.

The reduction in the amount of pesticide used on agricultural crops in the Province of Ontario from 1983 to 2003 met the goal of the Food Systems 2002 program. There was also a reduction in pesticide use per hectare of crop area, per tonne of production, and per dollar of crop value. The reduction in pesticide risk was greater than the reduction in pesticide use because of the shift to lower risk pesticides.

INTRODUCTION

The Ontario Survey of Pesticide Use conducted every five years since 1973 provides real use data as a basis for program evaluation, program and policy development, and the development of risk mitigation strategies. Since 1983 the data have been used as a benchmark to assess the reduction in pesticide use attributable to the Food Systems 2002 program of the Ontario Ministry of Agriculture and Food. Food Systems 2002 was an election platform of the Ontario Liberal Party during the 1987 provincial election campaign. The platform stated simply that the Province of Ontario would undertake a program to reduce agricultural pesticide use by 50% by the year 2002, with the proviso "while maintaining our agricultural productivity." The Liberal Party won the 1987 election and instituted the Food Systems 2002 program. This was a 15-year program with three main components (Surgeoner and Roberts 1992): 1) mandatory pesticide education programs for approximately 40,000 growers (at their request), 2) hiring of 11 integrated pest management (IPM) personnel, and 3) approximately $800,000.00 per annum for research to develop new methods to reduce pesticide use (e.g. IPM programs, banding of pesticides). The goal of the program was to reduce pesticide use to 50% of the amount used in 1983, the last year for which pesticide use data was available in 1987. The 2003 pesticide use survey (McGee, Berges and Callow 2004) revealed that pesticide use on agricultural crops in Ontario declined by 51.7% from 1983 to 2003, indicating that the Food Systems 2002 goal of a 50% reduction in agricultural pesticide use has been achieved.

Food Systems 2002 used the amount of active ingredient as the measure of pesticide use. However, a common criticism is that the reduction in pesticide use simply results from the replacement of "high volume-low risk" pesticides by "low volume-high risk" pesticides, and that there is little or no reduction in the environmental risks asssociated with pesticide use. Most would agree that the objective of any pesticide reduction program should be to reduce the risk to non-target organisms, and that reductions in the amount of pesticide used should be accompanied by equivalent or greater reductions in environmental risk.

In previous analyses of the changes in pesticide use and risk in the Province of Ontario (Gallivan et al. 1998, 2001, Gallivan and Kovach 2000), pesticide use and risk increased from 1973 to 1983, then declined from 1983 to 1998. Pesticide use declined 38.5% and risk declined by 39.5% from 1983 to 1998. Most of the reduction in pesticide use and risk occurred on corn and tobacco, the crops with highest pesticide use in 1983. The reduction in pesticide use and risk on tobacco resulted from a decrease in acreage and a substantial reduction in pesticide use per hectare. Pesticide use and risk per hectare also declined on corn and soybeans, but there was no change in net use and risk on soybeans because of the increase in acreage. Tobacco, fruits and vegetables had the highest pesticide use and risk per hectare, however, unlike tobacco, there was no reduction in pesticide use and risk per hectare of fruits and vegetables from 1983 to 1998. These analyses indicate that changes in pesticide use and risk over time are influenced not only by programs to reduce pesticide use, but also by changes in other factors, such as crop area and pesticide use strategies on different crops.

Risk is a function of the toxicity of a chemical and the exposure to that chemical. The previous analyses of pesticide risk (Gallivan et al. 1998, 2001, Gallivan and Kovach 2000) used the environmental impact quotient (EIQ) (Kovach et al. 1992) as a measure pesticide risk. The EIQ calculates a risk score for individual pesticides based on the potential toxicity and exposure of farmworkers, consumers, fish, birds, bees and beneficial insects to that pesticide. The risk associated with pesticide use on crops was then calculated by multiplying the risk score for indiviual pesticides by the amount of each pesticide used. However, the EIQ has been criticized because the low range of scores (1, 3 or 5) assigned to various components may distort the risk differences between pesticides with markedly different toxicities and exposures, and because of the value judgements inherent in the model (Dushoff et al. 1994, Pease et al. 1996). Several other pesticide risk scoring systems have been developed (Levitan et al. 1995, Demers 2001), but different risk scores may be poorly correlated (Maud et al. 2001) and may produce substantially different rankings of pesticide risk (Pease et al. 1996). Thus, although the EIQ has been used in previous analyses, it is not the only risk score available.

The first analysis of pesticide risk on agricultural crops in Ontario from 1973 to 1983 (Gallivan et al. 1998) included EIQ scores for 129 pesticides. These were scores published in Kovach et al. (1992) and unpublished scores calculated by Kovach in 1996. The subsequent analysis of pesticide risk from 1983 to 1998 (Gallivan and Kovach 2000) included scores for an additional 9 pesticides from Kovach et al (1992, unpublished 1996) plus the scores for an additional 38 pesticides calculated by the authors. This included the scores for 7 pesticides registered after 1992. These scores were based on available published information. However, there was often a substantial amount of information missing for the toxicity and exposure potential of various pesticides. The scores for many pesticides were approximated based on the characteristics of other pesticides in the class or of a similar type.

An amendment to the US Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) in 1988 accelerated the reregistration of pesticide active ingredients registered prior to 1984. The US Food Quality Protection Act (FQPA) of 1996 further amended FIFRA to require reassessment of all pesticide tolerances in existence in 1996 by the year 2006. Since the passage of the FQPA, the US Environmental Protection Agency (EPA) has undertaken major re-evaluation of the risks associated with the use of older pesticides. In Canada, a similar program to re-evaluate all pesticides registered prior to 1995 was initiated by the Pest Management Regulatory Agency (PMRA) in 1999. The re-evaluation ensures that the risk assessment for older pesticides meets current regulatory standards. Missing data must be provided, submitted studies must meet internationally recognized standards, and the toxicity and exposure endpoints are re-assessed using current scientific standards. All re-evaluations, including a summary of the toxicity and exposure data used in making the assessment, are published on the EPA or PMRA websites. The re-evaluation of older pesticides in the US and Canada has not only provided greater information on many older pesticides, but has also changed the interpretation of the toxicity of many pesticides. Thus, many of the risk scores used in the earlier analyses of pesticide use and risk in Ontario did not reflect the current risk assessment of many pesticides.

The primary objective of the current study was to assess the risk associated with pesticide use on agricultural crops in Ontario in 2003 to determine if the Food Systems 2002 goal of a 50%

reduction in agricultural pesticide use was matched by a 50% reduction in risk. As part of the risk assessment the EIQ scores for all pesticides were re-evaluated to reflect the current risk assessment of individual pesticides. The risk assessment was also conducted using other risk scoring systems to allow an evaluation of the robustness of the changes in pesticide risk over time.

METHODS

Pesticide Use and Crop Production

The data required for this project were the amount of pesticide (active ingredient) used, the risk for each pesticide, and the area of crop production, the crop yield and the crop value. The amount (kg) and type (phenoxy herbicide (hp), triazine herbicide (ht), other herbicide (ho), insecticide (i), fungicide (f), nematocide (n)) of each pesticide used on each crop (Appendix 1, 2) were obtained from the surveys of pesticide use in Ontario from 1973 to 2003 (Roller 1975, 1979, McGee 1984, Moxley 1989, Hunter and McGee 1994, 1999, McGee, Berges and Callow 2004). The area of crop production (Table 1) was obtained from the pesticide use surveys prior until 1994. For the 1998 and 2003 surveys, the area of crop production was the area planted as of June 01. Crop yields (Table 2) and crop value (Table 3) were obtained from the agricultural statistics for Ontario (Ontario Ministry of Agriculture and Food 1974, 1979, 1984, 1989, 2005, Ontario Ministry of Agriculture, Food and Rural Affairs, 1994, 1999).

Pesticide Risk Assessment

Previous assessments of pesticide risk on agricultural crops in Ontario (Gallivan et al. 1998, 2001, Gallivan and Kovach 2000) have used the Environmental Impact quotient (EIQ) (Kovach et al. 1992) as a measure of the risk associated with individual pesticides. However, as noted above, the EIQ has been criticized because the low range of scores (1, 3 or 5) assigned to various attributes may distort risk assessment between pesticides with markedly different toxicities and use patterns, and because of the value judgements inherent in the model (Dushoff et al. 1994, Pease et al. 1996). Thus, one of the goals of this project was compare the changes in risk using different measures of risk for individual pesticides.

The first stage of the risk assessment was to survey the literature on pesticide scoring systems to select those applicable to the situation in Ontario. Selected scoring systems had to provide for a broad range of environmental impacts (human, avian, aquatic, beneficials, etc.) and had to be sufficiently flexible to incorporate a large number of pesticides. Secondly, a procedure was needed to combine the risk scores each pesticide into an overall score to allow the assessment of the changes in pesticide risk over time.

A number of systems for assessing pesticide risk have been developed (Levitan et al. 1995, Reus et al. 2001, Demers 2001). However, because they were limited in scope (i.e. water only, humans only) or required site specific information, few of the systems were applicable to a holistic assessment of the changes in pesticide risk in Ontario. After examining the available scoring systems, the most applicable were the Environmental Impact Quotient (Kovach et al. 1992), the Environmental Hazard Index (Pease et al. 1996), and the Priority Substances List (PSL) score (Koniecki et al. 1997). These are described in more detail below. All three systems add the scores for individual components without reference to an external standard, thereby allowing a comparison of the risks associated with the use of multiple pesticides over time.

An alternative approach used in some scoring systems (i.e. Hornsby et al 1993) is to use a risk ratio which compares the predicted environmental exposure to the allowable concentrations based on toxicity. This approach is used by regulatory agencies such as the PMRA and the US EPA. However, accurate risk ratios require detailed calculations of exposure, and while they are useful for individual pesticides, comparison of the relative risk among pesticides is difficult. The US EPA has developed a preliminary cumulative hazard and dose-response model for the organophosphate pesticides (U.S. Environmental Protection Agency 2001). This procedure is based on the potency of individual pesticides relative to an index pesticide. However, the calculation of relative potency is only applicable to chemicals with a common mechanism of toxicity (i.e. cholinesterase inhibition by the organophosphates), and cannot be used when mechanisms of toxicity differ.

Selected Scoring Systems

The selected scoring systems are described below and the input variables are presented in Table 4.

<u>Environmental Impact Quotient (EIQ)</u>

The EIQ measures the potential risk of pesticides to humans and the environment. It differs most scores in that the toxicity is multiplied by the potential exposure to calculate the risk score. The EIQ is calculated using the formula:

$$EIQ=\{C[(DT*5)+(DT*P)]+[(C*((S+P)/2)*SY)+(L)]+[(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]\}/3$$

where:
C = chronic toxicity (reproductive, developmental, genotoxicity and carcinogenicity)
DT = dermal toxicity (acute rat/rabbit dermal LD_{50})
P = plant surface half-life (weeks)
S = soil half-life (days)
SY = systemicity (mode of action and systemic absorption in plants)
L = leaching potential
F = fish toxicity (96-hr LC_{50})

R = runoff potential
D = bird toxicity (8-day LC_{50})
Z = bee toxicity
B = beneficial arthropod toxicity

All of the input variables are scored as 1, 3 or 5, except for chronic toxicity which is the average of the scores for reproductive toxicity, teratogenicity/developmental toxicity, genotoxicity/ mutagenicity and carcinogenicity.

Environmental Hazard Index (EHI)

The EHI is a composite score based on several hazard measures, with each measure scored using an elicited hazard function of the form $u = 100e^{-nx}$ or $u = 100(1 - e^{-nx})$ based on whether the score is rising or falling with increasing toxicity. The hazard measures in the score are: mammalian oral LD_{50}, cancer index (Q_1*), reference dose, annual illnesses, acute avian LD_{50}, invertebrate LC_{50}, fish LC_{50}, bioconcentration factor, well detections, solubility, half-life and adsorption coefficient. Scores of 0 - 100 are calculated for each measure. The final EHI was the average of all of the scores.

Priority Substances List (PSL) Score

The PSL score is also a composite score based on several hazard measures, with each measure scored 0 -10. The PSL score includes the following measures: acute toxicity (oral and dermal LD_{50}, and inhalation and aquatic LC_{50}), subchronic/chronic toxicity in non-mammals for both aquatic and terrestrial environments, phytotoxicity in water, air and soil, subchronic/chronic toxicity in mammals, developmental toxicity, genotoxicity, carcinogenicity, enviromental presence, environmental persistence (half-life) and bioaccumulation. The PSL is the cumulative score.

Calculating Risk Scores

Prior to calculating the pesticide risk using the three methods it was necessary to ensure that risk scores were available for each pesticide. EIQ scores were available for 178 pesticides used up to 1998, but EHI scores were only available for 81 pesticides, and PSL scores were only available for 4. In addition, there were 22 “new” pesticides in the 2003 pesticide use survey. There were registered since 1997, or had been classified as “other” because of limited use in previous surveys.

A secondary goal of this project was to update the EIQ scores using pesticide re-evaluations from the US EPA and the PMRA. Because of the number of pesticides with missing scores for the EHI and PSL, it was also necessary to obtain information on these pesticides to allow a meaningful comparison of the three scoring systems, as well as calculate risk scores for the “new” pesticides.

To update the EIQ scores and to calculate the missing scores for the EHI, PSL and the "new" pesticides, an extensive search of the available databases was conducted. The primary search focused on the Reregistration Eligibility Decision (RED) documents published by the US EPA (http://cfpub.epa.gov/oppref/rereg/status). All of the REDs, including the electronic dockets (EDOCKET) (http://docket.epa.gov/edkpub/do/EDKStaffQuickSearchResults), available as of April 30, 2005 were reviewed. The EPAs New Active Ingredient fact sheets (http://www.epa.gov/opprd001/factsheets/) were searched for pesticides registered since 1997, and the EPA Federal Register Environmental Documents website (http://www.epa.gov/fedrgstr/) was searched for updated information available during the assessment of pesticide tolerances. A search was also conducted of the documents published by PMRA (http://www.pmra-arla.gc.ca/english/pubs/pubs-e.html) on the registration of new pesticides (PRDD, RDD and REG series) and the re-evaluation of existing pesticides (PACR and RDD series).

REDs and/or EDOCKETS were available for 102 pesticides listed in the pesticide use surveys in Ontario from 1973 to 1998. Information on an additional 12 pesticides was obtained from the PMRA RDDs, PRDDs or Reg Notes. Information for 20 pesticides registered since 1997 was obtained from the EPA New Active Ingredient fact sheets and from the PMRA website. However, these sources did not always provide all of the information needed for each pesticide, and there were 210 pesticides in the pesticide use database. Where information for individual pesticides was missing, other sources were searched. These included the California Environmental Protection Agency Department of Pesticide Regulation toxicology summaries (http://www.cdpr.ca.gov/docs/toxsums/toxsumlist), the International Programme on Chemical Safety (IPCS) INCHEM database (http://www.inchem.org/), the US Department of Agriculture Research Service Pesticide Properties Database (http://www.arsusda.gov/acsl/services/ppdb/ppdb3.html), the Health Canada Water Quality and Health website (http://www.hc-sc.gc.ca/hecs-sesc/water/dwgsup.htm), the US National Library of Medicine TOXNET database (http://toxnet.nlm.nih.gov/) which includes the Hazardous Substances Data Bank (http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB) and the Integrated Risk Information System (http://www.epa.gov/iris/index.html). Other sources also searched were EXTOXNET Pesticide Information Profiles (http://extoxnet.orst.edu/pips/ghindex.html), the Herbicide Handbook (Humburg et al. 1989, Ahrens 1994, Hatzios 1998, Vencill 2002), The Pesticide Manual (Tomlin 1997, 2003), the Farm Chemicals Handbook '99 (Meister 1999), the Pesticide Fact Handbook (US Environmental Protection Agency 1988), and the Guide to Chemicals Used in Crop Protection (Spencer 1982). Additional sources for aquatic toxicity were Johnson and Finley (1980) and Mayer and Ellersieck (1986). Additional information on beneficial insect toxicity was obtained from published results of the IOBC programme (Hassan et al. 1983, 1987, 1988, 1991). Literature searches were conducted for individual pesticides using the US NLM TOXLINE (http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?TOXLINE) when data could not be found in other sources. Where data were available from several sources, information from studies that conformed to OECD/OPPTS regulatory standards was chosen.

The following data were extracted for each pesticide for human health hazards: acute oral LD_{50}, acute dermal LD_{50}, acute inhalation LD_{50},subchronic oral NOAEL, subchronic inhalation

NOAEL, chronic NOAEL, ADI or RfD (cPAD), reproductive toxicity, developmental toxicity, carcinogenicity and the genotoxicity/ mutagenicity. The ADI or RfD included any additional uncertainty factors because of data gaps, and any additional safety factors mandated under the FQPA.

For environmental effects, the data extracted were: freshwater fish 96-hr LC_{50}, freshwater invertebrate LC_{50}, freshwater aquatic plant LC_{50}, avian acute LD_{50}, avian 5(8)-day LC_{50}, bee LD_{50}, beneficial toxicity, soil half-life, water half-life, plant surface half-life, soil adsorption coefficient (K_{OC}), water solubility, vapour pressure, plant systemicity, octanol-water partition coefficient (log K_{OW}), bioconcentration factor (BCF), leaching potential and runoff potential. Where leaching potential and runoff potential were not explicitly stated, they were estimated using the Groundwater Ubiquity Score (GUS) (Gustafson 1989) and the Relative Leaching Potential Index (RLPI) and Relative Runoff Potential Index (RRPI) (Hornsby et al. 1993). When possible, field data, preferably Canadian, were used for soil half-life and water half-life. However, estimates based on metabolism, hydrolysis or model simulations were used when field data were not available, or were considered unreliable. Plant surface half-life was based on dislodgeable foliar residues. However, when this data was not available estimates based on photodegradation, volatilization or metabolism were used. Where a range of values was available for environmental half-lifes and coefficients, the average or median value was usually selected unless some of the values were clearly not applicable to conditions in Ontario. Where a range of values was available, the calculations of the GUS, RLPI or RRPI were made using extreme values to examine the sensitivity of the assessment under different conditions. In contrast, values for aquatic and avian toxicity were usually based on the lowest relevant values. For beneficial toxicity based on the IOBC results, the following criteria were selected: average score 1-1.5 = low, average score 1.5-2.5 = moderate, average score >2.5 = high. For pre-emergent herbicides, beneficial insect toxicity is unlikely. However, there is potential toxicity to earthworms, thus earthworm toxicity was used a substitute for beneficial toxicity for pre-emergent herbicides when insect toxicity was not available.

The EIQ, EHI and PSL scores were then calculated for each pesticide. In calculating the EHI, no data were available for two variables, annual illnesses and well detections. Therefore these measures were excluded from the calculated score. In calculating the PSL, phytotoxicity and environmental presence were excluded because all herbicides are phytotoxic, and because environmental presence was measured by the amount of pesticide used. The acute lethality and subchronic non-mammalian effects were also adjusted to more closely conform with the other two scoring systems. Acute lethality was confined strictly to acute mammalian toxicity. Aquatic toxicity was scored separately using the fish 96-hr LC_{50}, invertebrate LC_{50} or aquatic plant IC_{50}. The score for aquatic toxicity was the highest score obtained after comparing the the fish 96-hr and inveterbrate LC_{50}s to the acute lethality aquatic LC_{50} , and the aquatic plant IC_{50} to the subchronic effects aquatic IC or EC_{50}. Avian toxicity was used as a measure of non-mammalian toxicity. The acute avian LD_{50} was scored using the acute lethality oral LD_{50}, and the 5(8)-day avian LC_{50} was scored using the subchronic effects non-mammalian terrestrial subchronic NOAEL. The 5(8)-day avian LC_{50} is normally expressed as ppm of diet, however, the subchronic NOAEL is expressed as mg/kg/day. Ppm of diet was converted to mg/kg/day by dividing by 8, the conversion factor for chicks (WHO 1990). The Environmental persistence score in the PSL was based on the soil half-life.

Despite an extensive literature search, there were data gaps for several pesticides, particularly older pesticides withdrawn from the market or that have not been re-evaluated. In calculating the EIQ and EHI scores, data gaps were assigned the median score for other pesticides in the same class or for other pesticides of the same type (fungicide, phenoxy herbicide, etc.). Because the EHI requires an actual measurement, the use of median scores for similar pesticides was not practical. The two variables in the EHI score for which data was missing most frequently were the avian acute LD_{50} and the BCF. Input values for the missing data for these variables were estimated from regression equations of avian acute LD_{50} versus avian 5(8)-day LC_{50}, and BCF versus log K_{OW}.

Calculating Pesticide Risk

To calculate the pesticide risk, the risk score (EIQ, EHI or PSL) for each pesticide was multiplied by the amount of that pesticide used on each crop. Because low use pesticides were often assigned to the category of "other" or "related" in the pesticide use surveys, and risk scores could not be calculated for all pesticides, the risk for each crop was underestimated. To adjust for the missing risk scores, the risks for all pesticides on each crop was summed by pesticide type and multiplied by a correction factor obtained by dividing the amount of pesticide of a given type used on each crop by the amount of pesticide for which risk scores were available. The majority of the 244 correction factors were 1 or <1.1. There were 3 correction factors for the EHI that were >2, and 12 in the range of 1.1 - 2.0. For the EIQ and PSL, only two correction factors were >2, and 4 and 5 were in the range of 1.1 - 2.0 for the EIQ and PSL respectively. Individual pesticide use data was not provided for fruits and vegetables in 1973, or for "other field crops" in 1998. To calculate the risks for fruits and vegetables in 1973, the average risk score for each pesticide type was calculated using the scores for all pesticides of that type registered prior to 1971. For "other field crops" in 1998, the average risk score was calculated using the scores for all pesticides of that type used in 1998.

The risk for each crop was obtained by summation of the risks for each pesticide type each year. The risks were then calculated as a percentage of the risk in 1983, the baseline year for the Food Systems 2002 program. Risks were also calculated on a per ha basis to account for changes in crop area, per kg of pesticide used to account for changes the pesticides used, and per tonne of crop production and per dollar of crop value.

RESULTS

<u>Pesticide Use</u>

From 1973 to 1983 pesticide use in the Province of Ontario increased 46%, from 5.56 x 10^6 kg to 8.13 x 10^6 kg (Table 5), the crop area increased 1.5% (Table 1) and the mean application rate (kg per ha) increased 44% (Table 6). Increases in the area and mean application rate on corn and soybeans accounted for most of the increased pesticide use. From 1983 to 2003 total pesticide use declined 49.5% to 4.10 x 10^6 kg, but the mean application rate only declined 45.6% because of a 7.2% decrease in the crop area. The reduction in pesticide use from 1983 to 1998 occurred on corn and tobacco. From 1998 to 2003 pesticide use also declined on fruits and vegetables. There were slight increases in pesticide use on field beans and grains from 1983 to 2003, and slight decreases on soybeans and hay and pasture. Some of the decreased use on other crops was offset by the added pesticide use on canola, ginseng, sod, and nursery crops, and other field crops.

Herbicides accounted for 49% of the pesticides used in 1973 and 68% in 1983 (Table 7) because of the increased use of herbicides on corn and soybeans. Triazine herbicide use declined 1.78 x 10^6 kg from 1983 to 2003, primarily because of the decreased use of atrazine and cyanazine on corn. However, herbicides still accounted for 82% of the total pesticide used in 2003 because of the decreased nematocide use on tobacco and the decreased use of insecticides on corn, fruits and vegetables.

Despite the decrease in pesticide use from 1983 to 2003 there was a 9.7% increase in production (Table 2), and a 18.2% increase in production per ha (Table 8). Pesticide use per tonne of production declined 54% from 1983 to 2003 (Table 9). However, the decrease in pesticide use per dollar of crop value was only 35% (Table 10) because the relative crop value in 1983 dollars declined 22.4% from 1983 to 2003 (Table 3).

Pesticide Risk

EIQ scores were calculated for 207 pesticides (Appendix 3), EHI scores were calculated for 199 (Appendix 4), and PSL scores were calculated for 205 (Appendix 5). The Pearson correlation coefficient between the risk scores ranged from 0.49 to 0.70, and the Spearman rank correlation coefficient ranged from 0.56 to 0.74 (Table 11). There was little consistency among the worst pesticides ranked by each method (Table 12). Nevertheless, all three scoring systems followed similar trends. Pesticide risk measured by the EIQ increased 29.5% from 1973 to 1983, from 164.6 x 10^6 to 213.2 x 10^6, then declined 52.0% to 102.4 x 10^6 in 2003 (Table 13). The change in risk measured with the EHI increased 35.4% from 1973 to 1983, then decreased 60.5% from 1983 to 2003 (Table 14), and the change measured with the PSL inceased 39.7% from 1973 to 1983, then decreased 59.0% from 1983 to 2003 (Table 15).

The mean EIQ per kg of pesticide declined 10.5% from 1983 to 1998, but increased slightly in 2003 and there was only a 5% decrease from 1983 to 2003 (Table 16). The EIQ per ha (Table 17) and EIQ per tonne of production (Table 18) declined progressively from 1983 to 2003, and were 48.2% and 56.2% lower respectively in 2003 than in 1983. The EIQ per dollar value (Table 19) also declined, with most of the decline occurring after 1993. The EIQ per dollar was 38.1% lower in 2003 than in 1983.

The EHI per kg of pesticide declined progressively from 1983 to 2003, and was 21.9% lower in 2003 than in 1983 (Table 20). The EHI per ha (Table 21) and EHI per tonne of production (Table 22) declined progressively from 1983 to 2003, and were 57.5% and 64.0% lower respectively in 2003 than in 1983. The EHI per dollar (Table 23) was 50.0% lower in 2003 than in 1983, with most of the decline occurring after 1993.

The PSL per kg of pesticide did not change 1983 to 1993, but declined more rapidly after 1993, and was 18.9% lower in 2003 than in 1983 (Table 24). The PSL per ha (Table 25) and PSL per tonne of production (Table 26) declined progressively from 1983 to 2003, and were 55.9% and 62.7% lower respectively in 2003 than in 1983. The PSL per dollar of crop value (Table 27) did not change appreciably from 1983 to 1993, but declined from 1993 to 2003. The PSL per dollar was 47.2% lower in 2003 than in 1983.

For all three systems the reduction in risk from 1983 to 2003 was greater than the reduction in pesticide use. This is confirmed by the reduction in risk per kg of pesticide of 5 - 22%. There was also a reduction in the number and amount of "high risk" pesticides from 1983 to 2003 using all three scoring systems (Table 28). The reductions were largest with the EHI, for which there was a 96% reduction in the amount of the highest scoring pesticides used. The 73.6% reduction in amount of "high risk" pesticides scored using the EIQ also exceeded the total reduction in pesticide use.

Individual Crops

Corn

More pesticides were applied to corn than any other crop in all of the pesticide surveys (Table 5). However, corn covered the second largest area after hay and pasture (Table 1). Pesticide use on corn doubled from 1973 to 1983 because a 38.5% increase in area and a 43.5% increase in the mean application rate. Corn accounted for 34% of the total pesticide use in 1973 and 47% in 1983. The increased use of herbicides accounted for 98.5% of the increased pesticide use on corn from 1973 to 1983, and 72.5% of the total increase in pesticide use.

Pesticide use on corn declined 59.7% from 1983 to 2003 because of a 18.3% decrease in area and a 50.7% decrease in the mean application rate, but corn still accounted for 37.6% of the total pesticide use in 2003. The use of triazine use herbicides decreased by 75.5% from 1983 to 2003 (Appendix 2). Atrazine use declined 67%, from 1.72 x 10^6 kg in 1983 to 0.50 x 10^6 kg in 2003, and cyanazine use declined 99.9%, from 0.43 x 10^6 kg to 443 kg (Appendix 1). The use of "other" herbicides decreased by 44.2%. Alachlor, which accounted for 16% of the pesticide use on corn in 1983, was discontinued after 1988, and butylate, which accounted for 7.6% of the pesticide use in 1983, was discontinued after 1998. These herbicides were replaced by metolachlor, s-metolachlor, dimethenamid, glyphosate, pendimethalin and the sufonylureas (nicosulfuron, rimsulfuron and prosulfuron). The use of phenoxy herbicides increased 2.6-fold from 1983 to 2003, primarily because of the increased use of dicamba. Insecticide use, which accounted for 3.8% of the pesticide use on corn in 1983, declined by 96.6%, and insecticides accounted for only 0.3% of the pesticides used on corn in 2003.

Crop yield for corn increased 50% from 1973 to 1983, but there wasn't a consistent trend from 1983 to 2003. The yield in 2003 was 8% higher than in 1983. Yield per ha increased slightly from 1973 to 2003. Yield per ha was 38.6% higher in 1998 than in 1983, and 32.2% higher in 2003 than in 1983. Pesticide use per tonne of production increased 33.5% from 1973 to 1983, then decreased consistently from 1983 to 2003. Pesticide use per tonne was 62.7% lower in 2003 than in 1983. Crop value in 1983 dollars decreased 45% from 1983 to 1988, and remained at 45 - 50% of the 1983 value. Pesticide use per dollar doubled from 1973 to 1983, and continued to increase until 1993 when it was 28.2% higher than in 1983. Pesticide use per dollar declined from 1993 to 2003, and in 2003 was 23.4% lower than in 1983

Corn had the second highest risk after tobacco in 1973 using all three scoring systems, and the highest risk in the subsequent surveys. Corn accounted for approximately 45% of the total pesticide risk in 1983 using all three scoring systems, and 35 - 40% in 2003. The changes in risk for corn over time were similar for all three scoring systems. The risk increased approximately 2-fold from 1973 to 1983, then declined approximately 64% from 1983 to 2003. The risk per tonne of production declined approximately 67% from 1983 to 2003, and the risk per dollar declined 30 - 33%. The increase in risk from 1973 to 1983 reflected the increase in pesticide use. The decline in risk from 1983 to 2003 was slightly larger than the decrease in pesticide use because the risk per kg of pesticide declined 10 - 12%. The reduction in pesticide risk per kg resulted from the reduced use of atrazine and cyanazine, and the elimination of alachlor and butylate. Their replacements, metolachlor/s-metolachlor, glyphosate, dicamba, dimethenamid and the sulfonylureas, tended to have lower scores in all three scoring systems.

The reduction in the use of insecticides on corn also contributed to the reduction in the risk scores as insecticides consistently had higher risk scores than the herbicides. Even though insecticides accounted for <4% of the pesticides applied to corn in 1983, the reduced use of insecticides on corn accounted for 40% of the total reduction in insecticide use on agricultural crops from 1983 to 2003.

Soybeans

There was 4.5-fold increase in the area of soybeans from 1973 to 1998, then a decrease of about 5% in area from 1998 to 2003. Pesticide use increased from 0.36 x 10^6 kg in 1973 to 1.70 x 10^6 kg in 1988 when soybeans replaced tobacco as the crop with second highest pesticide use. Pesticide use on soybeans declined to 1.14 x 10^6 kg in 1993, increased to 1.29 x 10^6 kg in 1998, then declined to 1.2 x 10^6 kg in 2003. The increase in pesticide use on soybeans from 1973 to 1983 resulted from 90% increases in both the area and the mean application rate. From 1983 to 2003 pesticide use on soybeans declined 6.6%. The mean application rate declined 58%, but the area inceased by 122.4%. Herbicides accounted for ∃99% of the pesticides applied to soybeans each year.

The crop yield for soybeans increased consistently from 1973 to 1998 when the yield was 3.24 times the yield in 1983. The yield declined in 2003, but was still 2.4 times the yield in 1983. Yield per ha was relatively constant from 1973 to 1983, then increased 38.8% from 1983 to 1998. In 2003, the yield per ha declined and was only 7.7% higher than in 1983. Pesticide use per tonne of production doubled from 1973 to 1983, then declined 69% from 1983 to 1998. Pesticide use per tonne increased in 2003, but was still 61% lower than in 1983. The crop value for soybeans also increased consistently from 1973 to 1998, then declined in 2003. The value in 2003 was 43% higher than in 1983. Pesticide use per dollar of crop value tripled from 1973 to 1983, then increased 15% from 1983 to 1988. In 1993 and 1998, pesticide use per dollar was 38 - 40% lower than in 1983, and in 2003 pesticide use per dollar was 35% lower than in 1983.

The pesticides used on soybeans changed over time. "Other" herbicides were most common, although triazine herbicides accounted for 22.2% of the pesticide use in 1993. Triazine herbicide use declined 87.8% from 1993 to 2003. In 1973 chloramben and alachlor accounted for 65.7% of the pesticide use. In 1983, alachlor and metolachlor were the most commonly used herbicides (34.1 and 25.4% respectively), followed by metribuzin (15.0%) and linuron (11.3%). In 1988 and 1993, metolachlor (53.9% and 34.4% respectively) and metribuzin (13.9% and 22.2% respectively) were the most commonly used pesticides, followed by linuron (10.0%) in 1988 and by glyphosate (14.5%) in 1993. In 1998, metolachlor (42.9%) and glyphosate (29.6%) were the most commonly used pesticides, and in 2003 glyphosate (72.0%) and metolachlor/s-metolachlor (15.9%) were the most commonly used pesticides. The use of glyphosate increased from 0.28×10^5 kg in 1983 to 8.62×10^5 kg in 2003.

There was an approximately 3.5-fold increase in pesticide risk associated with soybeans from 1973 to 1983 using all three scoring systems. Soybeans had the third highest pesticide risk in 1983, and the second highest in the 1988 and later surveys using all three scoring systems. From 1983 to 2003 the changes risk for soybeans differed among the three scoring systems. There was a 43% reduction in risk 1983 to 2003 using the EHI and PSL. However, the risk with the EHI increased 24.5% from 1983 to 1988, then declined 18.5% relative to 1983 in 1993 and 1998. The risk using the PSL increased 33% from 1983 to 1988, then declined 16% relative to 1983 in 1993 and 1998. The risk using the EIQ was higher than the risk in 1983, except in 1993. In 2003 the risk using the EIQ was 36% higher than in 1983.

There were also marked differences in the trends in the risk per kg of pesticide among the three scoring systems. From 1973 to 1983, the risk per kg using the EIQ increased about 6%. The risk per kg declined about 5% using the EHI, and didn't change using the PSL. After 1983, the changes in risk per kg were similar using the EHI and PSL, and the risk per kg was approximately 38% lower in 2003 than in 1983 using both scoring systems. In contrast, the risk per kg calculated using the EIQ increased consistently from 1983 to 2003, and was 45.7% higher in 2003 than in 1983.

The risk per ha and risk per tonne of production approximately doubled from 1973 to 1983 using all three scoring systems. The risk per ha and risk per tonne declined consistently from 1983 to 2003 using the EHI and PSL. In 2003 the risks per ha and per tonne using both scores were approximately 75% lower than in 1983. In 1993 and 1998, the risk per ha using the EIQ was 49% lower than the risk per ha in 1983, but the risk increased in 2003 and was only 39% lower than in 2003. The risk per tonne was 63% lower in 1998 than in 1983, but increased in 2003 and was only 43% lower than in 1983.

The risk per dollar of crop value for soybeans increased 3-fold from 1973 to 1983 using all three scoring systems. The risk per dollar peaked in 1988 using all three scoring systems, then declined consistently using the EHI and PSL. The risk per dollar in 2003 was 60% lower than the risk in 1983 using the EHI and PSL. The risk per dollar using the EIQ was lowest in 1993 when it was 32% less than in 1983. In 2003 the risk per dollar using the EIQ was only 5% less than in 1983.

The marked differences among the trends in risk after 1983 resulted from differences among the scoring systems for the scores of individual pesticides, particularly the score for glyphosate which was the most commonly used pesticide in 2003. Glyphosate had an EIQ score of 26.7. This was substantially higher than the EIQ scores for two other major pesticides used during this period, metolachlor (EIQ = 15.3) and metribuzin (EIQ = 18). In contrast, the EHI and PSL scores for glyphosate (20.3 and 14 respectively) were much lower than the scores for metolachlor (EHI = 35.7, PSL = 28) and metribuzin (EHI = 45.1, PSL = 26). The apparent discrepancy between the relative scores for glyphosate and the other pesticides results from different use patterns. Glyphosate is a post-emergent herbicide, and is given a plant surface half-life score of 3 in the EIQ calculations. Metolachlor and metribuzin are pre-emergent or early post-emergent herbicides and are given a plant-surface half-life score of 1. Plant surface half-life is a component of many parts of the EIQ score, but is not a component of the EHI or PSL scores. If the plant surface half-life for glyphosate was also 1 based on the foliar dissipation half-life in forestry (US Environmental Protection Agency 1993), the modified EIQ score for glyphosate would be 12.7. This is less than the score for metolachlor. The relative difference in the two scores would then be consistent with the differences in the EHI and PSL scores.

<u>Field Beans</u>

Field beans covered 0.8 - 1.6% of the crop area. There weren't any obvious patterns in the changes in area and pesticide use among years. The area and pesticide use were relatively low in 1983. Pesticide use increased 275.5% from 1983 to 1988 because of a 67% increase in area and a 125% increase in the mean application rate. Both area and pesticide use declined from 1988 to 1998. The area in 1998 was only 5% less than in 1983, but pesticide use was 37% less because of a 34% decrease in the mean application rate. Crop area increased from 1998 to 2003. The crop area in 2003 was 33% higher than in 1983, but the pesticide use was similar because of a 23% reduction in the mean application rate.

The crop yield for field beans was lowest in 1983, but there weren't any consistent trends because of variability in crop area. Yield per ha declined from 1973 to 1978, then increased consistently. The yield per ha was 5% lower in 1978 than in 1983, and 91.7% higher in 2003 than in 1983. Pesticide use per tonne of production was also highly variable. Pesticide use per tonne peaked in 1988 at 2.28 times the 1983 use, and then declined. In 1998 and 2003 respectively, pesticide use per tonne was 62.2% and 59.7% lower than in 1983. The crop value of field beans also varied widely. The peak value in 1973 was 4.4 times the value in 1983. From 1983 to 2003, the value varied from approximately 1 - 1.5 times the 1983 value. The value in 2003 was 52% higher than in 1983. Pesticide use per dollar of crop value was also highly variable. Pesticide use per dollar of crop value was 61% lower in 1973 than in 1983, and peaked in 1988 at 2.44 times the 1983 value. In 1998 and 2003 respectively, pesticide use per dollar was 35.5% and 32.5% lower than in 1983

Herbicides accounted for ∃97% of the pesticide use. EPTC and metobromuron were the most commonly used pesticides in 1973 and 1978, accounting for 86.7% and 79.2% of the pesticide use in the two surveys. EPTC and metobromuron were still the most common pesticides in 1983, but only accounted for 54.5% of the pesticide use. Metolachlor accounted for 16.9%. Metolachlor accounted for 36.9% of the pesticide use in 1988, followed by metobromuron (15.8%) and trifluralin (8.9%). Metolachlor and metobromuron were also the most commonly used pesticides in 1993 and 1998 when they accounted for 49.8% and 37.6% of the pesticide use. Bentazon accounted for 15.5% of the pesticide use in 1993, and glyphosate for 15.5% in 1998. Glyphosate (40.0%) and trifluralin (19.8%) were the most commonly used pesticides in 2003, followed by bentazon (8.7%) and dimethoate (7.4%).

The changes in pesticide risk varied widely using all three scoring systems and generally mirrored the changes in pesticide use. The most substantial difference among the three scoring systems occurred in 2003, when the risk was 49% higher than in 1983 using the EIQ, the same as in 1983 using the EHI, and 16.6% lower than in 1983 using the PSL. The risk per kg using the EHI did not change substantially among the surveys from 1973 to 2003. In contrast, the risk per kg using the PSL began to decline in 1993, and was 18.8% lower in 2003 than in 1983. The risk per kg using the EIQ consistently increased from 1973 to 2003, and was 45.1% higher in 2003 than in 1983.

Again, the differences in risk scores among the three scoring systems accounted for much of the apparent differences in risk. Using the EIQ, the pesticides ranked as EPTC (8.3), trifluralin (9.3), metobromuron (12.3), metolachlor (15.3), bentazon (17.8), glyphosate (26.7) and dimethoate (27.3). Using the EHI, the ranks were glyphosate (20.3), metobromuron (26.7), EPTC (32.9), metolachlor (35.7), bentazon (42.5), trifluralin (46.7) and dimethoate (62.9). With the PSL, the rankings were glyphosate (14), bentazon (18), metobromuron (24), EPTC (26), metolachlor (28), dimethoate (32) and trifluralin (36).

The ranking of EPTC, metobromuron, metolachlor, bentazon, glyphosate and dimethoate with the EIQ was similar to the chronological order of their predominant use, resulting in an increase in the risk per kg over time. The increased importance of glyphosate in 2003 was a major factor in the increase in the EIQ. For the EHI and PSL, glyphosate had the lowest risk score. However, there was no change in risk using the EHI in 2003 because the impact of glyphosate was negated by bentazon, trifluralin and dimethoate which had scores 2.1 - 3.1 times higher than glyphosate. For the PSL, the risk declined in 2003 because the score for bentazon was only 1.3 times the score for glyphosate, and the scores dimethoate and trifluralin were 2.3 and 2.6 times higher respectively.

Grains

Grains, including rye, winter and spring wheat, oats, barley and mixed grains, covered the second largest area after hay and pasture in 1973. The area decreased by 29% from 1973 to 1998, from 9.08 x 10^5 ha to 6.41 x 10^5 ha, then increased to 7.06 x 10^5 ha in 2003. Pesticide use peaked in 1988, declined from 1988 to 1998, then increased from 1998 to 2003. The area in 2003 was 17% less than the area in 1983, but the pesticide use was 9% higher because of a 31.5% increase in the mean application rate. Despite the large area, grains had a low mean application rate relative to most other crops and accounted for <8% of the total pesticide use annually from 1973 to 1998, and only 10% of the total pesticide use in 2003.

Crop yield for grains was within 10% of the 1983 yield except in 1993 when it was 21.3% lower, and in 2003 when it was 31.3% higher. Crop yield per ha increased progressively from 1973 to 2003, and was 58.4% higher in 2003 than in 1983. Pesticide use per tonne of production was lowest in 1978, then increased until 1993 when it was 51% higher than in 1983. Pesticide use per tonne declined from 1993 to 2003, and 16.9% lower in 2003 than in 1983. Crop value for grains declined by 36% from 1973 to 1983, and 56.8% from 1983 to 1993. Crop value increased after 1993 and but was still 24.4% lower in 2003 than in 1983. Pesticide use per dollar of crop value for grains increased 61.4% from 1973 to 1983, and 2.76-fold from 1983 to 1993. Pesticide use per dollar declined from 1993 to 2003, but was still 44.2% higher in 2003 than in 1983.

Herbicides accounted for >99% of the pesticides used on grain, with phenoxy herbicides, particularly 2,4-D (amine and butyl) and MCP accounting for >95% of the pesticide used in 1973 and 1978. Phenoxy herbicides declined as a percentage of the pesticide used after 1978 because of the increased use of glyphosate and bromoxynil, and in 2003 phenoxy herbicides only accounted for 54% of the pesticide use. The most commonly used pesticides in 2003 were MCP (30.6%), glyphosate (25.1%), 2,4-D (22.9%) and bromoxynil (17.1%). Glyphosate use increased 2.74-fold from 1983 to 2003, and bromoxynil use increased 50-fold.

The changes in risk over time mirrored the changes in pesticide use with all three scoring systems. The risk per kg was within 5% of the 1983 risk in all surveys using the EHI. There was a similar pattern with PSL, except that the risk per kg increased 12% in 2003. In contrast, the risk per kg using the EIQ increased consistently from 1978 to 2003, and was 25% higher in 2003 than in 1983. Except for glyphosate which had the lowest score on the EHI and PSL, and the second highest score on the EIQ, the other four major pesticides had a similar ranking in all three scoring systems. From lowest to highest they were 2,4-D amine, 2,4-D butyl, MCP and bromoxynil. The changes in risk per kg using the EHI and PSL were similar, except in 2003. The higher risk per kg using the the PSL in 2003 resulted from higher ratio of the score for bromoxynil relative the other pesticides in the PSL. The ratios of the scores for bromoxynil to MCP were 1.1 and 1.75 in the EHI and PSL respectively, and the ratios of the scores for bromoxynil to glyphosate were 2.8 and 3.5 respectively. The consistent increase in the risk per kg using the EIQ resulted from the replacement of 2,4-D amine (EIQ = 14.7) and 2,4-D butyl (EIQ = 16.7) with MCP (EIQ = 24.5), glyphosate (EIQ = 26.7) and bromoxynil (EIQ = 42).

Hay and Pasture

Hay and pasture covered the largest area but had the lowest pesticide use from 1973 to 1983. The area declined 16% from 1973 to 1983, and 26% from 1983 to 2003. Pesticide use increased 3.75 times from 1983 to 1998, from 2.49×10^4 kg to 9.34×10^4 kg, then declined to 2.08×10^4 kg in 2003. Nevertheless, hay and pasture still accounted for <2% of the pesticide applied to agricultural crops in 1998. The increased pesticide use on hay and pasture from 1983 to 1998 resulted in part from an increase in the percentage of the area treated. Pesticides were applied to <2% of the area of hay and pasture in 1983 and >4% in 1988 and 1993.

Crop yield of hay and pasture, measured as yield of hay, was constant from 1973 to 1988. In 1993, yield was increased 14% relative to 1983, but yield declined in 1998 and 2003. Yield in 2003 was 15.2% lower than in 1983. Yield per ha increased 20.6% from 1973 to 1983, and 35% from 1983 to 1993. Yield per ha was the same in 1998 and 1983, but was 15% higher in 2003 than in 1983. Pesticide use per tonne was lowest in 1978 and increased until 1998 when it was 5 times the use per tonne in 1983. In 2003, pesticide use per tonne was similar to 1983. Crop value of hay and pasture varied from 1973 to 1988, then declined progressively. In 2003, crop value was 26.8% lower than in 1983. Pesticide use per dollar of crop value was lowest in 1978 and increased until 1998 when it was 4.48 times the use per dollar in 1983. In 2003, pesticide use per dollar was 13.8% higher than in 1983.

2,4-D was the most commonly used pesticide until 1983, and glyphosate was the most commonly used pesticide in the 1988 and later surveys. Glyphosate has a higher application rate than 2,4-D (Ontario Ministry of Agriculture, Food and Rural Affairs 1998) which also accounted for the increased pesticide use from 1988 to 1998.

The changes in pesticide risk using the three scoring systems mirrored the changes in pesticide use. However, after 1983 the changes in risk using the EHI and PSL were less than the changes in pesticide use, while the changes using the EIQ were greater than the changes in pesticide use. As noted above, pesticide use increased from 1983 to 1998, and was 3.53 and 3.74 times higher in 1993 and 1998 respectively than in 1983. In 2003 pesticide use was 16.6% lower than in 1983. The relative changes in risk using the EHI and PSL were similar. The risk in 1993 and 1998 was approximately 2.4 times the risk in 1983, and the risk in 2003 was approximately 46.5% lower. In contrast, the risk using the EIQ was 5.25 and 5.61 times higher in 1993 and 1998 respectively than in 1983, and 28.9% higher in 2003 than in 1983. The differences between the scoring systems were reflected in the risk per kg of pesticide. The risk per kg using the EHI and PSL declined from 1983 to 1998, and was approximately 36% lower in 1998 and 2003 than in 1983. In contrast, the risk per kg using the EIQ was approximately 50% higher from 1988 to 2003 than in 1983. This differences among the scoring systems occurred because glyphosate, which was the most commonly used pesticide after 1983, has a higher EIQ score than 2,4-D amine and 2,4-D butyl, but lower EHI and PSL scores than 2,4-Damine and 2,4-D butyl.

Tobacco

Tobacco covered approximately 1% of the area farmed from 1973 to 1983, but had the second highest pesticide use because the mean application rate was 9.5 - 16.7 times the mean application rate of corn. The crop area of tobacco declined 32.8% of the area from 1998 to 1983, and 57.3% from 1983 to 2003. Pesticide use on tobacco declined 81.4% from 1983 to 1998, from 1.67×10^6 kg to 0.31×10^6 kg, then increased to 0.35×10^6 kg in 2003, 79.3% less than in 1983. The mean application rate in 1998 was 27.7% of the mean application rate in 1983, but the mean application rate increased to 48.5% of the 1983 rate in 2003. The mean application rate in 2003 was 11 times the mean application rate of corn.

There was little variation among years in yield per ha, and the changes in crop yield of tobacco over time were similar to the changes in crop area. Tobacco consistently had the highest pesticide use per tonne of yield (Table 9), and despite the decrease in pesticide use from 1983 to 2003, the pesticide use per tonne in 1998 was still 8.7 times the pesticide use per tonne of fruits which had the second highest pesticide use per tonne. This ratio was similar to the ratio (8.8) in 1983. Tobacco had the highest value per ha of all of the crops until 2003 when it was replaced by ginseng, sod and nursery crops. Crop value per ha declined from 1973 to 2003, and was 17.8% lower in 2003 than in 1983. However, pesticide use per dollar of crop value on tobacco was generally lower than the use per dollar on corn, soybeans, field beans and fruits. Pesticide use per dollar of crop value on tobacco declined 68.7% from 1983 to 1998, then increased, although the pesticide use per dollar of crop value was still 41% lower in 2003 than in 1983.

Nematocides accounted for > 91.5% of the pesticides used on tobacco in all years except 1998 when they only accounted for 84.4% of the pesticide use. The reduced use of nematocides, primarily the dichloropropenes (1,3-dichloropropene and 1,2-dichloropropane), accounted for 99% of the reduction in pesticide use on tobacco from 1983 to 1998, and 96.7% of the reduction in use from 1983 to 2003. However, the increase in use of nematocides from 1998 to 2003 was twice the increase in total pesticide use, and there was decreased use of fungicides, herbicides and insecticides, suggesting that the use of nematocides may reduce the need for other pesticides.

The changes in pesticide risk on tobacco were similar using all three scoring systems. Risk declined approximately 82% from 1983 to 1998, then increased slightly in 2003 when the risk was 79.5% lower than in 1983. This was similar to the changes in pesticide use. Risk per kg of pesticide was consistent across years using all three scoring systems.

Fruits

Fruits covered 0.7 - 0.8% of the crop area, but had the fourth highest pesticide use from 1973 to 1988, and in 2003, and the third highest pesticide use in 1993 and 1998. Fruits had the second highest mean application rate after tobacco from 1978 to 1988, and in 2003, and the highest mean application rate in 1998. Pesticide use on fruits increased 80% from 1978 to 1993, from 0.35×10^6 kg to 0.63×10^6 kg, then declined to 0.25×10^6 kg in 2003. The increase in pesticide use from 1978 to 1983 resulted from a 61% increase in the mean application rate. From 1983 to 1993 both the area and mean application rate increased slightly. The area declined after 1993, and in 2003 was 11.2% lower than the area in 1983. The mean application rate in 2003 was 50.3% lower than in 1983.

The crop yield and yield per ha for fruits increased from 1973 to 1983. The yield and yield per ha were similar from 1983 to 1993. In 1998, the yield was 13% higher than in 1983, and was 6% lower in 2003 than in 1983. The yield per ha was 20% higher than in 1983 in 1998, and 5.9% higher in 2003. Fruits had the second highest pesticide use per tonne of yield after tobacco except in 1978 and 1988 when field beans had the second highest use. The crop value of fruits varied from 83% to 123% of the 1983 value, with the highest value in 1978 and the lowest value in 1993. The crop value in 2003 was similar to the value in 1983. Pesticide use per dollar of crop value doubled from 1978 to 1983, and increased 33.8% from 1983 to 1993. Pesticide use per dollar declined in 1998 and 2003, and was 55.3% lower in 2003 than in 1983.

In 1983 fungicides accounted for 73% of the pesticides applied to fruit, and insecticides accounted for 25.5%. Fungicide use increased to approximately 84.5% of the pesticide use in 1998 and 2003, and insecticide use declined to 12-13% of the pesticide use. The decrease in insecticide use on fruits was associated with a marked reduction in the use of carbaryl and the organophosphates, particularly azinphos-methyl, phosalone and phosmet, and an increased use of newer insecticides such as imidacloprid, pyridaben, spinosad, tebufenozide, cyhalothrin-lambda and other synthetic pyrethroids which are applied at lower rates than the older products (Ontario Ministry of Agriculture and Food, 2002a). The four most commonly used fungicides, captan, mancozeb, metiram and sulphur, accounted for >85% of the fungicide use in all years. Captan and mancozeb were the most commonly used fungicides in 1978 and 1993, captan and metiram were the most commonly used in 1983, mancozeb and metiram were the most commonly used in 1988 and 1998, and captan and sulfur were the most commonly used in 2003. From 1998 to 2003 there was a >70% reduction in the use of mancozeb and metiram.

Apples accounted for approximately 34% of crop area for fruits in 1978. The relative area increased to 43% in 1998, then declined to 35% in 2003. Apples accounted for approximately 50% of the pesticide use on fruits from 1978 to 1993 and 67% in 1998, but only 30% in 2003. Fungicide and insecticide use on apples were similar to the proportion of the pesticide use on apples relative to all fruits, except that apples accounted for 50% of the insecticide used on fruit in 2003.

Grapes had the second highest pesticide use on fruits in all of the surveys. In 1978 grapes accounted for 36% of the area of fruits, but the area declined approximately 40% from 1978 to 1993 when grapes only accounted for only 20% of the area of fruits. The area increased from 1993 to 2003 when grapes accounted for 30% of the area of fruits. Pesticide use on grapes ranged from 19 - 25% of the total pesticide use on fruits from 1978 to 1998, but increased to 43% in 2003. Fungicides accounted for most of the pesticides used on grapes, increasing from 59% in 1978 to 90% in 2003. Insecticides were the second most commonly used pesticides, but the use decreased from 37.6% in 1978 to 6.0 - 6.5% in 1998 and 2003. Fungicide and insecticide use on grapes were similar to the proportion of pesticides used on grapes relative to other fruits, except in 1998 and 2003 when the proportion of insecticides was much lower on grapes.

The changes in pesticide risk over time followed a similar pattern using all three scoring systems, and followed the changes in pesticide use. The changes tended to be largest with the EIQ and smallest with the PSL. The mean risk per kg of pesticide using the EIQ was 8.5% higher in 1988 than in 1983, and was 18.1% lower in 2003 than in 1983. The risk per kg using the EHI was 4.5% higher in 1988 than in 1983, and was 12.7% lower in 2003. The risk per kg using the EHI declined progressively from 1988 to 2003, whereas the risk per kg using the EIQ declined 5.5% relative to 1983 in 1993, then increased in 1998, and declined again in 2003. The risk per kg using the PSL was within 2.5% of the 1983 value from 1988 to 1998, and only declined 4.4% relative to 1983 in 2003.

The differences in the temporal trends for risk per kg among the three scoring systems reflected the differences in the scores for the major fungicides. The EIQ scores from lowest to highest were sulfur (12.7), captan (19), mancozeb (32.8) and metiram (46.5), while the EHI and PSL rankings were sulfur (EHI = 12.5, PSL = 24), mancozeb (EHI = 31.4, PSL = 32), captan (EHI = 37.1, PSL = 36) and metiram (EHI = 38.9, PSL = 42). There was an almost 4-fold differences in the EIQ scores for sulfur and metiram, and a 3-fold difference in the EHI score. However, the PSL score for metiram was only 1.75 times the score for sulfur. The ranges in the scores for captan, mancozeb and metiram were also much greater using the EIQ (27.5) than with the EHI (7.5) and PSL (10). The marked decline in the risk per kg in 2003 using the EIQ was due to the >70 reduction in the use of mancozeb and metiram from 1998 to 2003, and the inceased importance of sulfur and captan. The shift in insecticide use from carbaryl and the organophosphates did not appreciably affect the risk per kg because the risk scores for the newer compounds were similar to those of the products being replaced. Any reduction in risk associated with newer insecticides was the result of the reduced application rate.

Vegetables

Vegetables covered 1.7 - 1.8% of crop area. They ranked sixth in pesticide use from 1983 to 1993, and in 2003, and fifth in 1998. The mean application rate was the third highest among the crops, behind tobacco and fruits. The mean application rate was approximately half the application rate on fruits in 1978, but was only 23 - 31% of the mean application rate on fruits from 1983 to 2003. Pesticide use on vegetables increased 14% from 1983 to 1993, from 0.35 x 10^6 kg to 0.41 x 10^6 kg, because of a 21% increase in the mean application rate. From 1993 to 2003 pesticide use declined by 50%. In 2003 pesticide use was 0.24 x 10^6 kg, 34% lower than in 1983 because of a 37.6% decrease in the mean application rate.

The crop yield for vegetables increased consistently from 1973 to 2003, and in 2003 was 25.5% higher than in 1983. The yield per ha was 15 - 20% higher than in 1983 from 1988 to 2003. Pesticide use per tonne of production increased 5.6% from 1983 to 1993, then declined. In 2003 pesticide use per tonne was 47.4% lower than in 1983. The crop value and crop value per ha have been declining since 1978, and in 1998 and 2003 the crop value was approximately 18% lower than in 1983. The crop value per ha was 15.3% lower in 1998 than in 1983, and 22.1% lower in 2003. Pesticide use per dollar of crop value increased 28.4% from 1983 to 1993, then declined. In 2003 pesticide use per dollar was 20% lower than in 1983.

Fungicide use on vegetables decreased 16% from 1978 to 1983, then increased 33.7% from 1983 to 1993, before declining 25.7% from 1993 to 1998 and 40.0% from 1998 to 2003. Fungicides accounted for approximately 43.5% of the pesticides used on vegetables in 1978 and 1983, 50% in in 1988 and 1993, 46.4% in 1998, and 39.3% in 2003. Insecticide use declined 25% from 1978 to 1988, then increased 64.3% from 1988 to 1993. In 1998 and 2003, insecticide use was 75% lower than in 1993. Herbicide use on vegetables declined 57.1% from 1978 to 1993, then increased approximately 2-fold from 1993 to 1998 and 2003. In 2003, fungicide use on vegetables was 40.3% lower than in 1983, insecticide use was 67.6% lower, and herbicide use was 9.3% higher.

Potatoes and tomatoes received 82% of the fungicides used on vegetables in 1978, 78% in 1983, 85% in 1988, 59% in 1993, and 85% in 1998 even though they only covered 35 - 45% of the crop area. In 2003 potatoes and tomatoes accounted for 37% of the fungicide use on vegetables and 33% of the crop area. Potatoes and tomatoes accounted for 68.5% of the insecticides used on vegetables in 1978, 45% in 1983 and 1988, 57% in 1993, 17% in 1998, and 27% in 2003. Insecticide use on potatoes was 50% higher in 1993 than in 1983, and 98% higher on tomatoes. From 1993 to 1998 insecticide use declined 90% on potatoes and 96.5% on tomatoes. The marked decline in insecticide use on potatoes in 1998 resulted from the introduction of imidacloprid which was applied at much lower rates than the insecticides used previously (Ontario Ministry of Agriculture and Food 2002b). However, use of imidacloprid declined approximately 90% from 1998 to 2003.

Chlorothalonil and mancozeb were the most commonly used fungicides, except in 1978 when metiram and captafol were the most commonly used, and in 1993 when the use of maneb exceeded the use of mancozeb. Chlorothalonil use increased 3.5-fold from 1978 to 1993, then declined. In 2003 use was 50% higher than in 1978, but 16.5% less than in 1983. Chlorothalonil use also increased as a proportion of the fungicide used, from 17.6% in 1978 to 67.6% in 1998, then declined to 52.2% in 2003. Mancozeb use increased almost 3-fold from 1978 to 1988, then declined 80% in 1998, before increasing in 2003. The use of maneb, another dithiocarbamate, increased 6.6-fold from 1978 to 1993, but no use was reported in 1998 and 2003. Metiram use declined almost continuously from 1978 to 2003, and the use in 2003 was only 94% lower than in 1978. Overall, use of the dithiocarbamates increased from 40.7% of the fungicide use in 1978 to 51.5% in 1998, declined to 12.8% in 1998, and increased to 22.7% in 2003. Captafol, the fungicide with the second highest use in 1978 (17.6%), was no longer used by 1993. Copper compounds accounted for 16.6% of the fungicide use in 1978. Use declined and none were used in 1993. However, they accounted for 16.9% of the fungicide use in 1998 and 19.2% in 2003.

Carbamates and organophosphates accounted for >90% of the insecticide use in 1978 and 1983, and 65% in 2003. Most of the decline occurred because of the 93.8% reduction in the use of carbamates which accounted for 55% of the insecticide use on vegetables in 1983 and 10.4% in 2003. Organophosphates accounted for 36.5% of the insecticide use in 1983, 43.4% in 1994, and >53% in 1988, 1993 and 2003. Organophosphate use increased 87% from 1983 to 1993, then declined, and in 2003 was only 49% of the use in 1983. The three most commonly used carbamates were aldicarb, carbaryl and carbofuran. Aldicarb was the most commonly used insecticide in 1978 (21.6%). Use declined substantially in 1983 and it was not used after 1988. Carbofuran was the most commonly used insecticide in 1983 (35.6%). Use declined 97.6% from from 1983 to 2003. The use of carbaryl also peaked in 1983, but was only 38% of the use of carbofuran. Carbaryl use declined 85.4% from 1983 to 2003. Several organophosphates were used each year. In 1978, the most common organophosphates were disulfoton and diazinon, in 1983 it was chlorpyrifos and fonofos, in 1988 it was parathion and azinphos-methyl, in 1993 it was azinphos-methyl and dimethoate, in 1998 it was chlorpyrifos and trichlorfon, and in 2003 it was phosmet and azinphos-methyl.

The risk using all the scoring systems followed the changes in pesticide use, declining from 1978 to 1983, increasing from 1983 to 1993, then declining from 1993 to 2003. The relative risk reduction from 1983 to 2003 was 44.5% using the EHI and PSL, and 37.7% using the EIQ. From 1978 to 1998 there was little variation in the risk per kg of pesticide using all of the scoring systems. In 1993, risk per kg declined 7.5% relative to 1983 using all three systems. In 2003, the risk per kg was approximately 16% lower than in 1983 using the EHI and PSL, but only 6% lower using the EIQ. The complex patterns of pesticide usage on vegetables made interpretation of the changes in risk difficult. This was further complicated by marked differences among the scores for many pesticides using the three systems.

DISCUSSION

The increased pesticide use and risk on agricultural crops in the Province of Ontario from 1973 to 1983 were associated with increases in the total yield and yield per ha, primarily because corn replaced hay and pasture. From 1983 to 2003 pesticide use declined by 49.5%, achieving the goal set by the Food Systems 2002 program. Part of the reduction in pesticide use from 1983 to 2003 occurred because of the 7.2% decrease in crop area, but there was also a 45.6% reduction in the mean application rate. Nevertheless, the total yield increased 9.7% from 1983 to 2003, and the yield per ha increased by 18.2%. This represented a 117% increase in yield per kg of pesticide.

The pesticide risk declined by 52 - 60% depending on the scoring system. The reduction in risk was greater than the reduction in pesticide use, and all three scoring systems showed a reduction in risk per kg of pesticide. Thus, not only was there a reduction in pesticide use, there was also a shift to less toxic pesticides.

The reductions in pesticide use and risk from 1983 to 2003 were not equal for all crops. The greatest reductions in pesticide use and risk were on corn and tobacco, crops that accounted for 67% of the pesticide use in 1983. There were significant reductions in pesticide use and risk per ha and per tonne of yield on both crops. However, for both crops the reduction in pesticide risk resulted primarily from the reduction in pesticide use. There was a 10% reduction in risk per kg of pesticide for corn from 1983 to 2003, but no change in the risk per kg for tobacco.

Pesticide use on soybeans declined slightly from 1983 to 2003, but there was a 122% increase in area and 7.7% increase in yield per ha. Thus, there was a real decline in pesticide use based on the approximately 60% reduction in pesticide use per ha and per tonne of yield. Pesticide risk on soybeans declined approximately 43% using the EHI and PSL. However, the risk increased 36% using the EIQ. This apparent anomaly was caused by the increased use of glyphosate which had a higher risk score relative to the other major herbicides used on soybeans in the EIQ, and a lower relative risk score in the EHI and PSL. The higher risk score in the EIQ is because glyphosate is a post-emergent herbicide whereas the other major herbicide, metolachlor, is pre-emergent. If glyphosate was scored based on the foliar residue half-life, it had a lower EIQ score relative the other herbicides. Using the lower score, there was a 20% reduction in pesticide risk on soybeans from 1983 to 2003 (Table 29). The lower score for glyphosate also produced substantial reductions in the pesticide risk on field beans, grains, and hay and pasture, and the total reduction in pesticide risk was similar to that obtained using the EHI and PSL.

While most of the reduction in pesticide use was on the major field crops, corn and soybeans, and on tobacco, there was also a substantial reduction in pesticide use on fruits and vegetables in 2003. These crops had the highest application rates after tobacco. There was a marked reduction in the use of insecticides on fruits and vegetables in 1998 and 2003, and a reduction in the use of fungicides in 2003. The reduction in the use of insecticides coincided with a reduction in the use of carbamates and organophosphates. There was also a shift in the use of fungicides, with a substantial reduction in the use of dithiocarbamates in 2003. These shifts in usage patterns were associated with a decrease in the risk per kg of pesticide.

Factors Affecting the Reduction in Pesticide Use

A priori, one would like to assume that the reduction in pesticide use from 1983 to 2003 resulted from initiatives taken under the Food Systems 2002 program, such as grower education, IPM programs, and the development of new technologies. However, while these initiatives may have had an impact, other factors also contributed to the reduction in pesticide use.

First, there was a 7.2% decrease in crop area. However, most of the reduction in crop area occurred because of the reduction in the area of hay and pasture which had a low mean application rate. Also, the reduction in the area of hay and pasture exceeded the total reduction in crop area by 50%, indicating that some of the hay and pasture was replaced by other crops which have higher mean application rates. Thus, the reduction crop area had little impact on the total pesticide use.

A second major factor in the reduction in pesticide use was the change in cropping patterns driven by market forces and new varieties. From 1983 to 2003 there were significant reductions in the area of corn, grains, tobacco, and hay and pasture, and an increase in the area of soybeans. The shift from corn and grains to soybeans was facilitated by the introduction of new varieties of soybeans which have a shorter growing season and are better adapted to the Ontario climate. The increase in soybean production led to the rotational cropping of corn, soybeans and winter wheat/clover which reduced the need for pesticides and forced a change in the pesticides used. For example, the use of atrazine on corn declined by 71% from 1983 to 2003 because of the switch to alternate herbicides. Atrazine accumulates in soils and groundwater, and may damage subsequent crops. The increase in rotational cropping was also a factor in the 96.6% reduction in the use of insecticides to control corn rootworm which is not a significant pest of first-year corn.

The decrease in the area of tobacco, which had the highest mean application rate in 1983, resulted from social pressures on tobacco use. The reduction in area was also accompanied by a 51.5% reduction in mean application rate, primarily because of the reduced use of nematocides. Interestingly, the use of nematocides increased from 1998 to 2003, but there was a reduction in the use of fungicides, herbicides and insecticides.

The third factor responsible for the decline in pesticide use has been the introduction of new technologies. Several of the newer herbicides, such as fenoxaprop-ethyl, imazethapyr and the sulfonyl-ureas, are applied at rates of gm per ha rather than kg per ha (Vincell 2002), as are many of the newer fungicides and insecticides (Tomlin 2003). Improvements in the manufacture of existing pesticides have also increased the proportion of active ingredient per kg of pesticide. For example, fenoxaprop-P-ethyl, the active form of fenoxaprop-ethyl, requires 50% less pesticide, and s-metolachlor, the active form of metolachlor, requires 35% less pesticide (Hatzios, 1998). While s-metolachlor has not completely replaced metolachlor, the use of s-metolachlor exceeded the use of metolachlor in 2003. Had s-metolchlor not been available in 2003, the use of metolachlor would have increased pesticide use on corn by 6.7% and total pesticide use by 3.8%.

There have also been improvements in pesticide application, such as electrostatic sprayers, improved sprayer calibration and banding of pesticides, which have contributed to the reduction in pesticide use. The introduction and implementation of these new technologies can be attributed in part to the grower education and research components of Food Systems 2002. The introduction of IPM programs, particularly in the fruit and vegetable industries, may also have contributed to the reduction in pesticide use. Pesticide use on fruits and vegetables increased from 1983 to 1993, but declined from 1993 to 2003. IPM programs can reduce the pesticide use on individual crops by 23 - 61% (Gallivan et al. 2001).

Finally, the introduction of genetically modified (GM) crops may also reduce pesticide use and risk (Brimner et al. 2004). The introduction of Bt-corn, which accounted for 32% of the corn planted in Ontario in 2002 (Hategekimana and Beaulieu 2002), further reduced the need for insecticide use on corn. The introduction of GM soybeans is a major factor in the increased use of glyphosate on soybeans. GM soybeans increased from 18% of the area of soybeans planted in Ontario in 2000 to 34% in 2002 (Hategekimana and Beaulieu 2002). Glyphosate accounted for

15% of the pesticide use on soybeans in 1993, 30% in 1998, and 72% in 2003. However, the switch to glyphosate did not substantially reduce pesticide use as the mean application rate only declined from 1.65 to 1.48 kg per ha from 1993 to 2003. In fact, without the introduction of s-metolachlor in 2003, the mean application rate would not have decreased from 1998 to 2003. Nevertheless, the introduction of GM soybeans does appear to have contributed to the reduction in risk because glyphosate has lower hazard scores than metolachlor and the other herbicides.

Evaluating the Reduction in Risk

All three scoring systems indicate that reduction in pesticide risk from 1983 to 2003 was greater than the reduction in pesticide use. The EIQ had the smallest reduction in risk, but this was because of the impact of glyphosate. When glyphosate was scored on the basis of foliar residue half-life, the risk reduction with EIQ was similar to the risk reduction with the EHI and PSL.

In general, the changes in pesticide risk mirrored the changes in pesticide use. The risk per kg of pesticide on most crops was usually within 10% of the 1983 value. The overall reduction in the risk per kg using the EHI and PSL was primarily a function of the risk per kg on soybeans. Nevertheless, there was a reduction in both the number and amount of high risk pesticides used with all three scoring systems.

The inability of the risk scores to detect reductions in risk may result from a number of factors. One of these is that the "high risk" pesticides are often "low use" pesticides. For example, the average EIQ and EHI score for insecticides used on corn was >50% higher than the mean score for triazine herbicides. However, the reduction in triazine herbicide use was 11.5 times the reduction in insecticide use. Some of the triazine herbicides were replaced by sulfonylureas which have application rates of gm per ha versus kg per ha, and have much lower risk scores in all three scoring systems. However, because the use of sulfonylureas was only 3.5% of the use of triazine herbicides in 2003, the impact on risk per kg of pesticide was minimal. Thus, the reduction in triazine herbicide use was the determining factor in the reduction in risk. The impact of high use pesticides is also demonstrated by the effect of glyphosate on the risk scores for soybeans where differences in relative risk scores between glyphosate and the other herbicides in the EIQ and the EHI and PSL produced contradicting results on pesticide risk.

Comparing the Scoring Systems

There was limited agreement among the three scores calculated for individual pesticides using the three scoring systems, either with correlation coefficients or by comparison of the "worst" pesticides. The limited agreement among scoring systems is consistent with the results reported by Maud et al. (2001). The lack of agreement may stem from many factors. First, even though these systems were selected because they incorporated a broad range of risk factors, the risk factors differed among the three scoring systems. Secondly, the scoring systems have fundamental differences in their underlying structure. The EIQ multiplies toxicity by potential exposure to estimate the potential risk for each element of the score, whereas the EHI and PSL add toxicity and potential exposure as separate elements of the score. Thirdly, the range of scores differs among the three systems. The EIQ uses scores of 1, 3 or 5 (low, medium or high) for each category, although multiplication of the toxicity and exposure scores allows a broader range of scores for each element (eg. 1, 3, 5, 9, 15 or 25). The EHI and PSL are structurally similar, but the EHI uses a non-linear function to score each element from 0 - 100 whereas the PSL uses a linear stepwise score from 0 - 10.

The use of linear scoring systems in the EIQ and PSL reduces their sensitivity. For example, the scores for fish toxicity in the EIQ are assigned to logarithmic differences in the 96-hr LC_{50} (e.g. 1 = >10 ppm, 3 = 1 - 10 ppm and 5 = <1 ppm). Thus, thousand-fold differences in toxicity may only differ by a factor of 5, and hundred-fold differences may have the same score. The PSL has a broader range of scores, but each score corresponds to a logarithmic range (i.e. >1-10, >10-100) and thousand-fold differences in toxicity only differ by 6 scoring units. The non-linear scoring function in the EHI places allows a much greater weight to be given to “high risk” pesticides. For example, a thousand-fold difference in fish toxicity corresponds to a difference of almost 100 in the risk scores. However, for many categories of risk, such as genotoxicity and carcinogenicity, the non-linear scoring function in the EHI may not be appropriate. The battery of tests used to measure genotoxicity do not produce a single numeric endpoint, thus a score cannot be calculated. For carcinogenicity the EHI uses the Q_1*. However, use of this measure is usually limited to compounds “carcinogenic to humans” or “likely to be carcinogenic to humans”. These compounds are often genotoxic/mutagenic or cause tumours in animals by undefined mechanisms of action, or by mechanisms relevant to humans. For many non-genotoxic carcinogens with a defined mechansim of action, a margin of exposure (MOE) approach is preferred. There are also many compounds for which evidence of carcinogenicity is only “suggestive” or is “inadequate”. In the EHI scoring system carcinogens using the MOE approach and those for which evidence is only suggestive or is inadequate are assigned a score of 0, the same score a non-carcinogens.

Regardless of the scoring system chosen, defining toxicity is not without problems. The toxicity of a pesticide may vary widely among species. For example, the 96-hr LC_{50} of the insecticide azinophos-methyl was 0.0011 ppm for bluegill and 4.27 ppm for goldfish (Mayer and Ellersieck, 1986). Even within a species, factors such as size and stage of development, and water temperature, pH and hardness can cause several-fold differences in toxicity. Other toxicity measures such as the NOAEL are also sensitive to the dose levels used in the tests. The NOAEL may be underestimated when there is a large difference between the NOAEL and the LOEL, or when the toxicity is not achieved at the highest dose tested.

Defining exposure is also difficult. The potential exposure measures include half-life, solubility, vapour pressure and soil adsorption. However, timing of application may be as important as half-life in determining exposure to farmworkers, consumers and other species. Temperature may affect half-life, solubility and vapour pressure. Soil adsorption may vary widely depending on the soil structure and amount of organic matter. Also, measures of exposure may have limited value with modern production methods on large field crops which account for most of the pesticide use. Many changes in agricultural practice have reduced the potential for pesticide exposure to applicators, fieldworkers, consumers and the environment.

Policy Implications

The reduction in pesticide use from 1983 to 2003 achieved the goal set by the Food System 2002 program. Most of the reduction resulted from the 45.5% reduction in the mean application rate. This occurred because of the switch to newer pesticides applied at lower rates, more efficient application of pesticides, and the introduction of IPM programs which reduce pesticide use. During this period crop production increased by 10%, and there was a 54% reduction in pesticide use per tonne of production, indicating that reducing pesticide use has not reduced the efficacy of pest control. However, pesticide use per dollar of crop value only decreased by 35% because of the decrease in crop values.

The decrease in pesticide risk was greater than the decrease in pesticide use with all three scoring systems. Most of the reduction in pesticide risk resulted from the reduction in pesticide use, however, there was also a reduction in risk per kg of pesticide inidicating a shift to lower risk pesticides. There was a reduction in the number and amounts of "high risk" pesticides used in 2003 with all three scoring systems.

Most of the reduction in pesticide use from 1983 to 2003 was on corn and tobacco, the crops with the largest pesticide use in 1983. The amount of pesticide used on soybeans did not change from 1983 to 1998, but the mean application rate declined dramatically. Defining the goal of a pesticide use/risk reduction program solely in a historical context implies that limited resources should be targeted to further reductions in pesticide use on the large field crops, corn and soybeans. Indeed, replacing "high use" herbicides with "low use" herbicides can achieve dramatic reductions in pesticide use. Replacing atrazine applied at 2 kg per ha by rimsulfuron applied at 10 gm per ha would further reduce pesticide use on corn by >30%. However, even though corn and soybeans accounted for 66.5% of the pesticide use in 1998, they only accounted for 60 - 62% of the risk. Both crops have relatively low pesticide use and risk per ha and per tonne of production.

While there may be a lesser impact on pesticide use perhaps resources should be concentrated on "high risk" crops such as fruits, tobacco and vegetables. These crops consistently had the highest mean application rates and pesticide use per tonne of production. There was a marked reduction in pesticide use on all three crops from 1983 to 2003, with most of the reduction on fruits and vegetables coming between 1998 and 2003. Pesticide use on tobacco increased from 1998 to 2003, reversing a trend towards reduced use of nematocides. However, tobacco, fruits and vegetables are "high" value crops. Expressing pesticide use per dollar of crop value fruits and vegetables ranked below corn and soybeans in 2003. In terms of risk per dollar of crop value, they also ranked below corn and soybeans using the EIQ and EHI. Eliminating fruit and vegetable production may not be a viable policy option because of the economic and social value of these crops, but continued targeting of resources towards reduced pesticide use and alternate pest management strategies may achieve a more meaningful reduction in risk than further reductions in pesticide use on the large field crops.

Finally, in evaluating the changes in pesticide use in the Province of Ontario we should be aware that pesticide use surveys at 5-year intervals only provide snapshots of a given year. Pesticide use may vary from year to year because of external factors, such as market forces and weather, that influence the amount and type of pesticide used. Cold, wet springs and hot, dry summers, such as 1983, may delay crop development and reduce production (Ontario Ministry of Agriculture and Food 1983) independent of other factors. Weather may also influence the timing and intensity of pest pressure and pesticide use. The potential effects of weather and market forces on both pesticide use and production may be difficult to quantify, but affect both the baseline and the end-point in any comparison.

The Food Systems 2002 goal of a 50% reduction in agricultural pesticide use in the Province of Ontario has been achieved, and there has been a >50% reduction in pesticide risk. The reductions in pesticide use and risk have not been consistent across all crops, and pesticide use and risk have not changed or increased on some crops. The interpretation of the reduction of pesticide use and risk may also depend on the context in which the changes are assessed. Food Systems 2002 assessed the temporal changes in pesticide use in terms of amount of active ingredient. However, the relative amount of active ingredient may depend on the crop area, the crop production, the crop value, and the pesticide chosen. Appreciating the changing patterns of pesticide use and risk in different contexts over time should determine the directions for future research and interventions, and our interpretation of the success of the Food Systems 2002 program.

ACKNOWLEDGEMENTS

This research was funded by Ontario Ministry of Agriculture and Food New Directions Program, Environment Canada and Ontario Ministry of Agriculture and Food program funding.

REFERENCES

Ahrens, W.H. (ed). 1994. Herbicide handbook. 7th ed. Weed Science Society of America, Champaign, Illinois. 352 pp.

Brimner, T.A., G.J. Gallivan and G.R. Stephenson. 2004. Influence of herbicide-resistant canola on the environmental impact of weed management. Pest Management Science 61: 47-52.

Demers, I. 2001. Anayse et application d'outils de sélection environnementale de pesticides en usage B la ferme. M.Sc. Thesis, Universiténde Sherbrooke, Sherbrooke, Québec. 104 pp.

Dushoff, J., B. Caldwell, and Mohler, C.I. 1994. Evaluating the environmental effect of pesticides: A critique of the environmental impact quotient. American Entomologist (Fall 1994): 180-184.

Gallivan, G.J., G.A. Surgeoner and J. Kovach. 1998. An analysis of the reduction in the risk of pesticides used on crops in Ontario using the environmental impact quotient. Final Report for Food Systems 2002 Project. 107 pp.

Gallivan, G.J. and J. Kovach. 2000. Evaluating pesticide risk reduction on agricultural crops in the Province of Ontario from 1983 to 1998. Final Report for Food Sysyems 2002 Project SR-9008. 125 pp.

Gallivan, G.J., G.A. Surgeoner and J. Kovach. 2001. Pesticide risk reduction on crops in the Province of Ontario. Journal of Environmental Quality 30: 798-813.

Gustafson, D.I. 1989. Groundwater ubiquity score: a simple method for assessing pesticide leachability. Environmental Toxicology and Chemistry 8: 339-357.

Hassan, S.A., F. Bigler, H. Bogenschutz et al. 1983. Results of the second joint pesticide testing programme by the IOBC/WPRS working group 'Pesticides and Beneficial Arthropods'. Journal of Applied Entomology 95: 151-158.

Hassan, S.A., R. Albert, F. Bigler et al. 1987. Results of the third joint pesticide testing programme by the IOBC/WPRS working group 'Pesticides and Beneficial Arthropods'. Journal of Applied Entomology 103: 92-107.

Hassan, S.A., F. Bigler, H. Bogenschutz et al. 1988. Results of the fourth joint pesticide testing programme by the IOBC/WPRS working group 'Pesticides and Beneficial Arthropods'. Journal of Applied Entomology 105: 321-329.

Hassan, S.A., F. Bigler, H. Bogenschutz et al. 1991. Results of the fifth joint pesticide testing programme carried out by the IOBC/WPRS working group 'Pesticides and Beneficial Arthropods'. Entomophaga 36: 55-67.

Hategekimana, B. and M. Beaulieu. 2002. Genetically modified crops: steady growth in Ontario and Quebec. Vista on the Agri-Food Industry and the Farm Community. Statistics Canada. December, 2002 (http://www.statcan.ca/english/freepub/21-004-XIE/free.htm)

Hatzios, K.K. (ed). 1998. Herbicide handbook: Supplement to 7th ed. Weed Science Society of

America, Champaign, Illinois. 103 pp.

Hertwich, E.G., Pease, W.S., and Koshland, C.P. 1997. Evaluating the environmental impact of products and production methods: A comparison of six methods. Science of the Total Environment 196: 13-29.

Hornsby, A.G., T.M. Butler and R.B. Brown. 1993. Managing pesticides for crop production and water quality protection: practical grower guides. Agriculture, Ecosystems & Environment 46: 187-196.

Humburg, N.E., S.R. Colby, E.R. Hill, L.M. Kitchen, R.G. Lynn, W.J. McAvoy and R. Prasad. 1989. Herbicide handbook: 6th ed. Weed Science Society of America, Champaign, Illinois. 301 pp.

Hunter, C. and McGee, B. 1994. Survey of pesticide use in Ontario, 1993. Ontario Ministry of Agriculture, Food and Rural Affairs, Policy Analysis Branch, Economics Information Report No. 94-01, 31 pp.

Hunter, C. and McGee, B. 1999. Survey of pesticide use in Ontario, 1998. Ontario Ministry of Agriculture, Food and Rural Affairs, Policy Analysis Branch, Economics Information Report, 18 pp.

Johnson, W.W. and M.T. Finley. 1980. Handbook of acute toxicity of chemicals to fish and aquatic invertebrates.US Department of the Interior, Fish and Wildlife Service, Resource Publication 137, 98 pp

Koniecki, D., R. Newhook, G. Long, B.C. de Beyssac and A. Socha. 1997. Screening candidate substances for the second priority substances list under the Canadian Environmental Protection Act. Environmental Carcinogenicity and Ecotxicology Reviews C15: 41-59.

Kovach, J., C. Petzoldt, J. Degni and Tette, J. 1992. A method to measure the environmental impact of pesticides. New York's Food and Life Sciences Bulletin 139: 1-8.

Levitan, L., I. Merwin and Kovach, J. 1995. Assessing the relative environmental impacts of agricultural pesticides: the quest for a holistic method. Agriculture, Ecosystems & Environment 55: 153-168.

Maud, J., G. Edward-Jones and F. Quin. 2001. Comparative evaluation of pesticide risk indices for policy development and assessment in the United Kingdom. Agriculture, Ecosystems & Environment 86: 59-73.

Mayer F.L., Jr. and Ellersieck, M.R. 1986. Manual of acute toxicity: interpretation and database for 410 chemicals and 66 species of freshwater animals. US Department of the Interior, Fish and Wildlife Service, Resource Publication 160, 69 pp + Appendix 506 pp.

McGee, B. 1984. Survey of pesticide use in Ontario, 1983. Ontario Ministry of Agriculture and Food, Economics and Policy Coordination Branch, Economics Information Report No. 84-05, 39 pp.

McGee, B., H. Berges and K. Callow. 2004. Survey of pesticide use in Ontario, 2003. Estimates of pesticides used on field crops,fruit and vegetable crops, and other agricultural crops. Ontario Ministry of Agriculture and Food, Policy and Programs Branch, Economics Information Report, 18 pp.

Meister, R.T. (ed). 1999. Farm chemicals handbook '99. Meister Publ. Willoughby, Ohio. 960 pp.

Moxley, J. 1989. Survey of pesticide use in Ontario, 1988. Ontario Ministry of Agriculture and Food, Economics and Policy Coordination Branch, Economics Information Report No. 84-08, 40 pp.

Ontario Ministry of Agriculture and Food. 1974. Agricultural statistics for Ontario. Ontario Ministry of Agriculture and Food, Publication 20, 52 pp.

Ontario Ministry of Agriculture and Food. 1979. Agricultural statistics for Ontario. Ontario Ministry of Agriculture and Food, Publication 20, 54 pp.

Ontario Ministry of Agriculture and Food. 1983. Agricultural statistics for Ontario. Ontario Ministry of Agriculture and Food, Publication 20, 73 pp.

Ontario Ministry of Agriculture and Food. 1984. Agricultural statistics for Ontario. Ontario Ministry of Agriculture and Food, Publication 20, 80 pp.

Ontario Ministry of Agriculture and Food. 1989. Agricultural statistics for Ontario. Ontario Ministry of Agriculture and Food, Publication 20, 98 pp.

Ontario Ministry of Agriculture and Food. 2002a. Fruit production recommendations 2002-2003. Ontario Ministry of Agriculture, Food and Rural Affairs, Publication 360, 294 pp.

Ontario Ministry of Agriculture and Food. 2002b. Vegetable production recommendations 2002-2003. Ontario Ministry of Agriculture, Food and Rural Affairs, Publication 363, 291 pp.

Ontario Ministry of Agriculture, Food and Rural Affairs. 2005. Agricultural statistics for Ontario. (http://www.gov.on.ca/OMAFRA/english/stats)

Ontario Ministry of Agriculture, Food and Rural Affairs. 1994. Agricultural statistics for Ontario. Ontario Ministry of Agriculture, Food and Rural Affairs, Publication 20, 100 pp.

Ontario Ministry of Agriculture, Food and Rural Affairs. 1998. Guide to weed control 1998. Ontario Ministry of Agriculture, Food and Rural Affairs, Publication 75, 286 pp.

Ontario Ministry of Agriculture, Food and Rural Affairs. 1999. Agricultural statistics for Ontario. (http://www.gov.on.ca/OMAFRA/english/stats)

Pease, W.S., J. Liebman, D. Landy and D. Albright. 1996. Pesticide use in California. Strategies for reducing environmental health impacts. California Policy Seminar, University of California, Berkeley, 93 pp.

Reus, J.A.W.A., P.C. Leemdertse, C. Bockstaller et al. 2001. Comparing environmental risk indicators for pesticides: results of the European CAPER project. CLM. (http://www.clm.nl/_engels/e-publications.html)

Roller, N.F. 1975. Survey of pesticide use in Ontario, 1973. Ontario Ministry of Agriculture and Food, Economics Branch, Economics Information, 35 pp.

Roller, N.F. 1979. Survey of pesticide use in Ontario, 1978. Ontario Ministry of Agriculture and Food, Economics Branch, Economics Information, 35 pp.

Spencer, E.Y. 1982. Guide to chemicals used in crop protection. 7th ed. Agriculture Canada Publ 1093, 595 pp.

Surgeoner, G.A. and Roberts, W. 1992. Reducing pesticide use in the Province of Ontario: Challenges and progress. In: Pimentel, D., Lehman, H. (Eds.), The Pesticide Question: Environment, Economics and Ethics, Chapman and Hall, New York, pp. 206-223.

Tomlin, C.D.S. (ed). 1997. The pesticide manual. 11th ed. British Crop Protection Council, Farnham. 1606 pp.

Tomlin, C.D.S. (ed). 2003. The pesticide manual. 12th ed. British Crop Protection Council, Farnham. 1344 pp.

U.S. Environmental Protection Agency. 1988. Pesticide fact handbook. Noyes, Park Ridge, New Jersey, 827 pp.

U.S. Environmental Protection Agency. 1993. Reregistration eligibility decision (RED). Glyphosate. US Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances (http//:www.epa.gov/oppsrrd1/REDs/old_reds/glyphosate.pdf)

U.S. Environmental Protection Agency. 2001. Preliminary cumulative hazard and dose-response model for organophosphorus pesticides: determinastion of relative potency and points of departure for cholinesterase inhibition . US Environmental Protection Agency,Office of Prevention, Pesticides and Toxic Substances

(http//:www.epa.gov/scipoly/sap/2001/september/relativepotency.pdf)

Vincell, W.K. (ed). 2002. Herbicide handbook. 8th ed. Weed Science Society of America, Champaign, Illinois. 493 pp.

World Health Organization. 1990. Principles for the toxicological assessment of pesticide residues in food. International Programme on Chemical Safety, Geneva, Environmental Health Criteria 104 (http://www.inchem.org/documents/ehc/ehc/ehc104.htm)

TABLES

Table 1: Crop area (ha) of agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1998	98%	2003	03%
corn	758800	72.1	1019800	96.9	1052000	100.0	858000	81.6	809400	76.9	870100	82.7	859966	81.7
field beans	49400	154.4	67000	209.4	32000	100.0	53400	166.9	40500	126.6	30400	95.0	42495	132.8
fruits	30900	108.8	28400	100.0	28400	100.0	29000	102.1	30300	106.7	26700	94.0	25228	88.8
grains	907700	106.5	815400	95.7	852000	100.0	842700	98.9	613200	72.0	641400	75.3	706184	82.9
hay & pasture	2045400	118.9	1829200	106.3	1720000	100.0	1477000	85.9	1462600	85.0	1289300	75.0	1268137	73.7
oilseeds							26300		24200		26300		21044	
ginseng, sod & nursery											21200		25147	
other field crops													9146	
soybeans	190200	52.3	285300	78.4	364000	100.0	518000	142.3	688000	189.0	849800	233.5	809380	222.4
tobacco	43000	106.2	43000	106.2	40500	100.0	24300	60.0	28600	70.6	27200	67.2	17280	42.7
vegetables	69900	95.9	71000	97.4	72900	100.0	65900	90.4	68800	94.4	70200	96.3	77170	105.9
TOTAL	4095300	98.4	4159100	99.9	4161800	100.0	3894600	93.6	3765600	90.5	3852600	92.6	3861177	92.8

Table 2: Crop yield (tonnes) of agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1998	98%	2003	03%
corn	4096000	67.1	5202000	85.3	6101600	100.0	4547400	74.5	5455356	89.4	6995200	114.6	6595000	108.1
field beans	72484	188.3	76500	198.7	38500	100.0	63500	164.9	72600	188.6	64000	166.2	98000	254.5
fruits	203044	68.8	272857	92.5	294931	100.0	290885	98.6	290102	98.4	334007	113.2	277391	94.1
grains	2142360	94.8	2059200	91.1	2260300	100.0	2313300	102.3	1778200	78.7	2150800	95.2	2967000	131.3
hay & pasture	6618820	98.6	6451000	96.1	6715000	100.0	6620000	98.6	7711000	114.8	5040000	75.1	5695000	84.8
oilseeds							34000		38600		56700		42640	
ginseng, sod & nursery											97700		142580	
otherfield														
soybeans	396570	55.0	515600	71.5	721600	100.0	1124000	155.8	1741800	241.4	2338300	324.0	1728000	239.5
tobacco	107089	107.9	105690	106.5	99210	100.0	61600	62.1	72500	73.1	69971	70.5	44250	44.6
vegetables	1242678	91.3	1413471	103.8	1361784	100.0	1480825	108.7	1472626	108.1	1592572	116.9	1708901	125.5
TOTAL	14879045	84.6	16096318	91.5	17592925	100.0	16535510	94.0	18632784	105.9	18739250	106.5	19298762	109.7

Table 3: Crop value ($) of agricultural crops in the Province of Ontario from 1973 to 2003. All values are adjusted to 1983 dollars

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1998	98%	2003	03%
corn	999509	103.2	910794	94.0	968776	100.0	529924	54.7	479853	49.5	509915	52.6	509799	52.6
field beans	105786	438.9	47243	196.0	24100	100.0	37158	154.2	24219	100.5	23499	97.5	36655	152.1
fruits	124901	113.4	136260	123.7	110142	100.0	102490	93.1	91895	83.4	127842	116.1	108866	98.8
grains	505322	156.5	332483	103.0	322885	100.0	279952	86.7	139489	43.2	156849	48.6	244249	75.6
hay & pasture	393250	105.4	502575	134.7	373138	100.0	455670	122.1	354371	95.0	311968	83.6	273347	73.3
oilseeds					2830	100.0	8988	317.6	7928	280.1	13031	460.5	8402	296.9
ginseng, sod & nursery											131019		195135	
other field crops														
soybeans	204183	82.6	229290	92.7	247300	100.0	284712	115.1	354052	143.2	414855	167.8	354255	143.2
tobacco	457437	128.3	435895	122.2	356564	100.0	201300	56.5	215882	60.5	212248	59.5	125012	35.1
vegetables	258313	109.0	262022	110.6	237008	100.0	218288	92.1	210830	89.0	193305	81.6	195460	82.5
TOTAL	3048702	115.4	2856561	108.1	2642743	100.0	2118480	80.2	1878518	71.1	2094531	79.3	2051180	77.6

Table 4: Input variables used to calculate the risk scores using the three risk scoring methods, the Environmental Impact Quotient (EIQ), the Environmental Hazard Index (EHI) and the Priority Substance List (PSL) score.

Input Variable		Method		
		EIQ	EHI	PSL
Human Toxicity				
Acute	Oral LD_{50}		X	X
	Dermal LD_{50}	X		X
	Inhalation LD_{50}			X
Chronic	Oral NOAEL		X (RfD)	X
	Inhalation NOAEL			X
Reproductive toxicity		X		
Teratogenicity		X		X
Carcinogenicity		X	X	X
Mutagenicity		X		X
Annual Illnesses			X	
Aquatic Toxicity				
Acute	Aquatic LC_{50}			X
	Fish LC_{50}		X	
	Fish 96-hr LC_{50}	X		
Subchronic IC_{50}, EC_{50}, MATC or MOAEC				X
Terrestrial Toxicity (non-mammals)				
Subchronic NOAEL				X
Chronic NOAEL				X
Birds	Acute LC_{50}		X	
	8-day LC_{50}	X		
Bees		X		
Beneficials		X		
Phyrotoxicity				X

Environmental Persistence				
Half-life	Soil	X		
	Water	X		
	Plants	X		
	Not defined		X	X
Runoff potential		X		
Leaching potential		X		
Well Detections			X	
K_{OC}		X	X	
Solubility		X	X	
Bioaccumulation	Systemicity	X (plants)		
	K_{OW}			X
	BCF		X	X
Environmental Presence				X

Table 5: Pesticide use (kg) on agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1998	98%	2003	03%
corn	1909812	50.3	3142312	82.7	3798460	100.0	2585430	68.1	2411808	63.5	1988385	52.3	1531569	40.3
field beans	100360	171.0	163517	278.7	58680	100.0	220340	375.5	108947	185.7	36903	62.9	60252	102.7
fruits	985470	175.2	349400	62.1	562640	100.0	597230	106.1	628078	111.6	543004	96.5	248433	44.2
grains	364862	97.0	269800	71.7	376290	100.0	494530	131.4	448384	119.2	358713	95.3	410537	109.1
hay & pasture	30000	120.3	17810	71.4	24930	100.0	44490	178.5	88020	353.1	93418	374.7	20790	83.4
oilseeds							43210		10903		12383		13134	
ginseng, sod & nursery											46926		35749	
other field crops									2819		237		5991	
soybeans	356310	27.8	521220	40.7	1281880	100.0	1698200	132.5	1136556	88.7	1287956	100.5	1196997	93.4
tobacco	1813399	108.6	1258240	75.4	1669420	100.0	795440	47.6	575608	34.5	311032	18.6	345210	20.7
vegetables	0	0.0	421845	118.5	356020	100.0	393130	110.4	406573	114.2	331126	93.0	235058	66.0
TOTAL	5560213	68.4	6144144	75.6	8128320	100.0	6872000	84.5	5817696	71.6	5010083	61.6	4103720	50.5

Table 6: Pesticide use per hectare (kg/ha) on agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1998	98%	2003	03%
corn	2.52	69.7	3.08	85.3	3.61	100.0	3.01	83.5	2.98	82.5	2.29	63.3	1.78	49.3
field beans	2.03	110.8	2.44	133.1	1.83	100.0	4.13	225.0	2.69	146.7	1.21	66.2	1.42	77.3
fruits	31.89	161.0	12.30	62.1	19.81	100.0	20.59	104.0	20.73	104.6	20.34	102.7	9.85	49.7
grains	0.40	91.0	0.33	74.9	0.44	100.0	0.59	132.9	0.73	165.6	0.56	126.6	0.58	131.6
hay & pasture	0.01	101.2	0.01	67.2	0.01	100.0	0.03	207.8	0.06	415.2	0.07	499.9	0.02	113.1
oilseeds							1.64		0.45		0.47		0.62	
ginseng, sod & nursery											2.21		1.42	
other field crops													0.66	
soybeans	1.87	53.2	1.83	51.9	3.52	100.0	3.28	93.1	1.65	46.9	1.52	43.0	1.48	42.0
tobacco	42.17	102.3	29.26	71.0	41.22	100.0	32.73	79.4	20.13	48.8	11.44	27.7	19.98	48.5
vegetables	0.00	0.0	5.94	121.7	4.88	100.0	5.97	122.2	5.91	121.0	4.72	96.6	3.05	62.4
AVERAGE	1.36	69.5	1.48	75.6	1.95	100.0	1.76	90.3	1.55	79.1	1.30	66.6	1.06	54.4

Table 7: Pesticide use (kg) by type from 1973 to 2003.

TYPE	1973	1978	1983	1988	1993	1998	2003
fungicides	503490	389660	566890	629930	664356	649906	330070
other herbicides	1076457	1891562	2718450	2954940	2524986	2719006	2333077
phenoxy herbicides	429054	320142	436760	599600	642018	473082	441947
triazine herbicides	1236303	2000110	2364740	1538840	1061840	723905	583325
insecticides	653710	386070	430870	349230	372192	153186	83280
nematocides	1661199	1156600	1610610	799460	552304	290998	332021
TOTAL	5560213	6144144	8128320	6872000	5817696	5010083	4103720

Table 8: Crop yield per hectare (tonne/ha) of agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1998	98%	2003	03%
corn	5.40	93.1	5.10	87.9	5.80	100.0	5.30	91.4	6.74	116.2	8.04	138.6	7.67	132.2
field beans	1.47	122.0	1.14	94.9	1.20	100.0	1.19	98.8	1.79	149.0	2.11	175.0	2.31	191.7
fruits	6.57	63.3	9.61	92.5	10.38	100.0	10.03	96.6	9.57	92.2	12.51	120.5	11.00	105.9
grains	2.36	89.0	2.53	95.2	2.65	100.0	2.75	103.5	2.90	109.3	3.35	126.4	4.20	158.4
hay & pasture	3.24	82.9	3.53	90.3	3.90	100.0	4.48	114.8	5.27	135.0	3.91	100.1	4.49	115.0
oilseeds							1.29		1.60		2.16		2.03	
ginseng, sod & nursery											4.61		5.67	
other field crops														
soybeans	2.09	105.2	1.81	91.2	1.98	100.0	2.17	109.5	2.53	127.7	2.75	138.8	2.14	107.7
tobacco	2.49	101.7	2.46	100.3	2.45	100.0	2.54	103.5	2.54	103.5	2.57	105.0	2.56	104.5
vegetables	17.78	95.2	19.91	106.6	18.68	100.0	22.47	120.3	21.40	114.6	22.69	121.4	22.14	118.5
AVERAGE	3.63	85.9	3.87	91.6	4.23	100.0	4.25	100.4	4.95	117.1	4.86	115.1	5.00	118.2

Table 9: Pesticide use per tonne of crop yield (kg/tonne) on agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1998	98%	2003	03%
corn	0.47	74.9	0.60	97.0	0.62	100.0	0.57	91.3	0.44	71.0	0.28	45.7	0.23	37.3
field beans	1.38	90.8	2.14	140.2	1.52	100.0	3.47	227.7	1.50	98.5	0.58	37.8	0.61	40.3
fruits	4.85	254.4	1.28	67.1	1.91	100.0	2.05	107.6	2.17	113.5	1.63	85.2	0.90	46.9
grains	0.17	102.3	0.13	78.7	0.17	100.0	0.21	128.4	0.25	151.5	0.17	100.2	0.14	83.1
hay & pasture	0.00	122.1	0.00	74.4	0.00	100.0	0.01	181.0	0.01	307.5	0.02	499.3	0.00	98.3
oilseeds							1.27		0.28		0.22		0.31	
ginseng, sod & nursery											0.48		0.25	
other field crops														
soybeans	0.90	50.6	1.01	56.9	1.78	100.0	1.51	85.0	0.65	36.7	0.55	31.0	0.69	39.0
tobacco	16.93	100.6	11.91	70.7	16.83	100.0	12.91	76.7	7.94	47.2	4.45	26.4	7.80	46.4
vegetables	0.00	0.0	0.30	114.2	0.26	100.0	0.27	101.5	0.28	105.6	0.21	79.5	0.14	52.6
AVERAGE	0.37	80.9	0.38	82.6	0.46	100.0	0.42	90.0	0.31	67.6	0.27	57.9	0.21	46.0

Table 10: Pesticide use per dollar of crop value (kg/$) on agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1998	98%	2003	03%
corn	5.40	93.1	5.10	87.9	5.80	100.0	5.30	91.4	6.74	116.2	8.04	138.6	7.67	132.2
field beans	1.47	122.0	1.14	94.9	1.20	100.0	1.19	98.8	1.79	149.0	2.11	175.0	2.31	191.7
fruits	6.57	63.3	9.61	92.5	10.38	100.0	10.03	96.6	9.57	92.2	12.51	120.5	11.00	105.9
grains	2.36	89.0	2.53	95.2	2.65	100.0	2.75	103.5	2.90	109.3	3.35	126.4	4.20	158.4
hay & pasture	3.24	82.9	3.53	90.3	3.90	100.0	4.48	114.8	5.27	135.0	3.91	100.1	4.49	115.0
oilseeds						100.0	1.29		1.60		2.16		2.03	
ginseng, sod & nursery						100.0					4.61		5.67	
other field crops														
soybeans	2.09	105.2	1.81	91.2	1.98	100.0	2.17	109.5	2.53	127.7	2.75	138.8	2.14	107.7
tobacco	2.49	101.7	2.46	100.3	2.45	100.0	2.54	103.5	2.54	103.5	2.57	105.0	2.56	104.5
vegetables	17.78	95.2	19.91	106.6	18.68	100.0	22.47	120.3	21.40	114.6	22.69	121.4	22.14	118.5
AVERAGE	3.63	85.9	3.87	91.6	4.23	100.0	4.25	100.4	4.95	117.1	4.86	115.1	5.00	118.2

Table 11: Correlation coefficents between the risk scores for individual pesticides using the three scoring systems. All of the correlations were highly significant (p < 0.001).

Pearson			**Spearman Rank**		
	EHI	**PSL**		**EHI**	**PSL**
EIQ	0.49	0.53	**EIQ**	0.56	0.56
PSL	0.70		**PSL**	0.75	

Table 12: 24 pesticides with the highest risk scores for each of the three scoring systems rank from highest to lowest.

EIQ	**EHI**	**PSL**
leptophos	aldicarb	copper, metallic
phosmet	acrolein	copper sulfate
benomyl	methomyl	demeton
cyhalothrin-lambda	dinitrocresol	chlordane
chlorfenvinphos	fensulfothion	fensulfothion
oxythioquinox	carbofuran	copper oxychloride
dinocap	terbufos	fonofos
flusilazole	phorate	paraquat
cyhexatin	mevinphos	methoxychlor
demeton	propoxur	bromoxynil
methoxychlor	demeton	niclofen
dicofol	oxydemeton methyl	parathion
fensulfothion	fonofos	copper hydroxide
oxydemeton methyl	isofenphos	chlorpyrifos
dinoseb	endosulfan	carbofuran
ioxynil	formetanate	dinitrocresol
copper, metallic	parathion	ethion
chlordane	dichlorvos	abamectin
copper sulfate	ethion	terbufos
dinitrocresol	oxamyl	propargite
propargite	methylisothiocyanate	dinoseb
metiram	disulfoton	diquat
dichlorprop	chlorfenvinphos	endosulfan
fonofos	chlorpyrifos	phorate

Table 13: Pesticide risk measured with the EIQ (x 10^6) on agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1
corn	51.76	53.4	78.64	81.1	97.00	100.0	62.21	64.1	54.03	55.7	
field beans	1.20	146.6	2.05	249.4	0.82	100.0	3.50	425.9	1.78	216.6	
fruits	30.41	157.9	12.16	63.2	19.26	100.0	22.18	115.2	20.31	105.5	
grains	7.15	90.8	5.04	63.9	7.88	100.0	10.94	138.9	10.12	128.4	
hay & pasture	0.56	138.9	0.33	83.2	0.40	100.0	1.08	269.3	2.11	525.4	
oilseeds							1.41		0.15		
ginseng, sod & nursery											
other field crops									0.08		
soybeans	5.47	26.2	8.34	39.9	20.88	100.0	28.32	135.6	20.27	97.1	
tobacco	68.08	117.7	42.56	73.6	57.86	100.0	27.36	47.3	19.75	34.1	
vegetables			11.70	129.0	9.07	100.0	10.30	113.6	10.46	115.4	
TOTAL	164.63	77.2	160.82	75.4	213.17	100.0	167.30	78.5	139.07	65.2	1

Table 14: Pesticide risk measured with the EHI (x 10^6) on agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	1
corn	78.37	50.7	128.31	83.0	154.56	100.0	100.40	65.0	92.64	59.9	
field beans	3.22	158.2	5.39	264.7	2.04	100.0	8.07	396.1	3.93	192.9	
fruits	46.52	213.5	14.74	67.6	21.79	100.0	24.17	110.9	23.84	109.4	
grains	14.30	98.6	9.99	68.8	14.50	100.0	19.35	133.4	16.41	113.2	
hay & pasture	1.19	132.4	0.67	75.0	0.90	100.0	1.32	147.0	2.18	243.2	
oilseeds							1.91		0.48		
ginseng, sod & nursery											
other field crops									0.17		
soybeans	15.28	29.1	22.56	42.9	52.55	100.0	65.45	124.5	41.62	79.2	
tobacco	110.79	108.6	76.56	75.0	102.02	100.0	48.28	47.3	34.84	34.1	
vegetables			19.92	117.9	16.90	100.0	17.95	106.2	19.99	118.3	
TOTAL	269.66	73.8	278.14	76.1	365.27	100.0	286.90	78.5	236.10	64.6	1

Table 15: Pesticide risk measured with the PSL (x 10^6) on agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	19
corn	54.60	50.8	89.71	83.4	107.54	100.0	73.00	67.9	68.11	63.3	
field beans	2.65	165.8	4.40	274.7	1.60	100.0	6.04	377.0	2.87	179.3	
fruits	35.70	181.0	12.33	62.5	19.72	100.0	21.41	108.6	21.48	108.9	
grains	8.61	98.5	6.13	70.1	8.74	100.0	11.79	134.9	10.29	117.7	
hay & pasture	0.77	126.8	0.46	75.8	0.61	100.0	0.86	140.9	1.45	237.6	
oilseeds							1.28		0.37		
ginseng, sod & nursery											
other field crops									0.10		
soybeans	9.95	28.4	14.21	40.5	35.07	100.0	46.64	133.0	29.40	83.8	
tobacco	58.71	110.9	40.47	76.4	52.94	100.0	25.10	47.4	17.98	34.0	
vegetables			15.21	120.1	12.66	100.0	13.26	104.7	14.07	111.1	
TOTAL	171.00	71.6	182.92	76.6	238.89	100.0	199.38	83.5	166.12	69.5	1

Table 16: Risk per kg of pesticide using the EIQ for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	19
corn	27.10	106.1	25.03	98.0	25.54	100.0	24.06	94.2	22.40	87.7	
field beans	12.00	85.7	12.53	89.5	14.00	100.0	15.88	113.4	16.33	116.7	
fruits	30.85	90.2	34.81	101.7	34.22	100.0	37.13	108.5	32.34	94.5	
grains	19.60	93.6	18.67	89.2	20.94	100.0	22.12	105.7	22.56	107.8	
hay & pasture	18.61	115.4	18.79	116.5	16.13	100.0	24.34	150.9	24.00	148.8	
oilseeds							32.72		13.81		
ginseng, sod & nursery											
other field crops									29.57		
soybeans	15.36	94.3	15.99	98.2	16.29	100.0	16.68	102.4	17.83	109.5	
tobacco	37.54	108.3	33.83	97.6	34.66	100.0	34.40	99.3	34.31	99.0	
vegetables			27.73	108.9	25.48	100.0	26.20	102.8	25.74	101.0	
AVERAGE	29.61	112.9	26.17	99.8	26.23	100.0	24.35	92.8	23.90	91.1	

Table 17: Risk per ha of crop area using the EIQ for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	19
corn	68.21	74.0	77.12	83.6	92.21	100.0	72.50	78.6	66.76	72.4	
field beans	24.37	95.0	30.57	119.1	25.67	100.0	65.51	255.2	43.93	171.2	
fruits	983.99	145.1	428.28	63.2	678.02	100.0	764.66	112.8	670.27	98.9	6
grains	7.88	85.2	6.18	66.8	9.25	100.0	12.98	140.4	16.50	178.4	
hay & pasture	0.27	116.8	0.18	78.2	0.23	100.0	0.73	313.6	1.44	617.9	
oilseeds							53.75		6.22		
ginseng, sod & nursery											
other field crops											
soybeans	28.77	50.2	29.22	50.9	57.37	100.0	54.67	95.3	29.46	51.4	
tobacco	1583.27	110.8	989.82	69.3	1428.63	100.0	1126.10	78.8	690.57	48.3	3
vegetables			164.76	132.4	124.41	100.0	156.30	125.6	152.09	122.2	1
AVERAGE	40.20	78.5	38.67	75.5	51.22	100.0	42.96	83.9	36.93	72.1	

Table 18: Risk per tonne of crop production using the EIQ for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	19
corn	12.64	79.5	15.12	95.1	15.90	100.0	13.68	86.0	9.90	62.3	
field beans	16.61	77.9	26.77	125.5	21.33	100.0	55.09	258.2	24.51	114.9	
fruits	149.75	229.4	44.58	68.3	65.29	100.0	76.23	116.8	70.01	107.2	
grains	3.34	95.8	2.45	70.2	3.49	100.0	4.73	135.7	5.69	163.2	
hay & pasture	0.08	140.9	0.05	86.6	0.06	100.0	0.16	273.2	0.27	457.5	
oilseeds							41.58		3.90		
ginseng, sod & nursery											
other field crops											
soybeans	13.80	47.7	16.17	55.9	28.94	100.0	25.19	87.1	11.64	40.2	
tobacco	635.74	109.0	402.71	69.1	583.20	100.0	444.23	76.2	272.42	46.7	1
vegetables			8.28	124.3	6.66	100.0	6.96	104.4	7.11	106.7	
AVERAGE	11.06	91.3	9.99	82.5	12.12	100.0	10.12	83.5	7.46	61.6	

Table 19: Risk per dollar of crop value using the EIQ for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%
corn	51.78	51.7	86.35	86.2	100.13	100.0	117.39	117.2	112.61	112.5
field beans	11.38	33.4	43.36	127.2	34.08	100.0	94.14	276.2	73.46	215.5
fruits	243.44	139.2	89.26	51.1	174.83	100.0	216.36	123.8	221.00	126.4
grains	14.15	58.0	15.15	62.1	24.40	100.0	39.07	160.1	72.53	297.3
hay & pasture	1.42	131.8	0.67	61.8	1.08	100.0	2.38	220.5	5.96	553.2
oilseeds							157.29		18.99	
ginseng, sod & nursery										
other field crops										
soybeans	26.80	31.7	36.36	43.1	84.44	100.0	99.46	117.8	57.25	67.8
tobacco	148.83	91.7	97.64	60.2	162.27	100.0	135.94	83.8	91.49	56.4
vegetables			44.65	116.7	38.27	100.0	47.19	123.3	49.63	129.7
AVERAGE	54.00	66.9	56.30	69.8	80.66	100.0	78.97	97.9	74.03	91.8

Table 20: Risk per kg of pesticide using the EHI for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%
corn	41.04	100.8	40.83	100.4	40.69	100.0	38.83	95.4	38.41	94.4
field beans	32.11	92.5	32.99	95.0	34.73	100.0	36.63	105.5	36.08	103.9
fruits	47.21	121.9	42.18	108.9	38.73	100.0	40.48	104.5	37.96	98.0
grains	39.19	101.7	37.01	96.0	38.55	100.0	39.13	101.5	36.61	95.0
hay & pasture	39.53	110.0	37.71	105.0	35.93	100.0	29.59	82.4	24.75	68.9
oilseeds							44.20		44.36	
ginseng, sod & nursery										
other field crops									60.87	
soybeans	42.87	104.6	43.29	105.6	41.00	100.0	38.54	94.0	36.62	89.3
tobacco	61.09	100.0	60.84	99.6	61.11	100.0	60.70	99.3	60.52	99.0
vegetables			47.22	99.5	47.47	100.0	45.66	96.2	49.16	103.6
AVERAGE	48.50	107.9	45.27	100.7	44.94	100.0	41.75	92.9	40.58	90.3

Table 21: Risk per ha of crop area using the EHI for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	19
corn	103.28	70.3	125.82	85.6	146.92	100.0	117.02	79.6	114.45	77.9	
field beans	65.24	102.4	80.52	126.4	63.68	100.0	151.14	237.3	97.05	152.4	
fruits	1505.47	196.2	518.97	67.6	767.29	100.0	833.56	108.6	786.77	102.5	7
grains	15.75	92.5	12.25	71.9	17.02	100.0	22.96	134.9	26.77	157.2	
hay & pasture	0.58	111.3	0.37	70.5	0.52	100.0	0.89	171.2	1.49	286.0	
oilseeds							72.62		19.99		
ginseng, sod & nursery											
other field crops											
soybeans	80.32	55.6	79.09	54.8	144.37	100.0	126.35	87.5	60.49	41.9	
tobacco	2576.45	102.3	1780.37	70.7	2519.09	100.0	1986.92	78.9	1218.07	48.4	6
vegetables			280.55	121.0	231.84	100.0	272.39	117.5	290.50	125.3	2
AVERAGE	65.85	75.0	66.88	76.2	87.77	100.0	73.67	83.9	62.70	71.4	

Table 22: Risk per tonne of crop production using the EHI for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	19
corn	19.13	75.5	24.67	97.4	25.33	100.0	22.08	87.2	16.98	67.0	
field beans	44.46	84.0	70.52	133.2	52.93	100.0	127.10	240.1	54.14	102.3	
fruits	229.11	310.1	54.02	73.1	73.89	100.0	83.10	112.5	82.17	111.2	
grains	6.67	104.0	4.85	75.6	6.42	100.0	8.36	130.3	9.23	143.8	
hay & pasture	0.18	134.3	0.10	78.1	0.13	100.0	0.20	149.1	0.28	211.8	
oilseeds							56.17		12.53		
ginseng, sod & nursery											
other field crops											
soybeans	38.52	52.9	43.76	60.1	72.83	100.0	58.23	80.0	23.89	32.8	
tobacco	1034.53	100.6	724.34	70.4	1028.36	100.0	783.80	76.2	480.51	46.7	2
vegetables			14.09	113.5	12.41	100.0	12.12	97.7	13.57	109.4	
AVERAGE	18.12	87.3	17.28	83.2	20.76	100.0	17.35	83.6	12.67	61.0	

Table 23: Risk per dollar of crop value using the EHI for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%
corn	78.41	49.1	140.88	88.3	159.54	100.0	189.46	118.8	193.06	121.0
field beans	30.47	36.0	114.19	135.0	84.56	100.0	217.21	256.9	162.29	191.9
fruits	372.45	188.3	108.17	54.7	197.85	100.0	235.86	119.2	259.42	131.1
grains	28.30	63.0	30.03	66.9	44.92	100.0	69.12	153.9	117.67	262.0
hay & pasture	3.02	125.6	1.34	55.7	2.40	100.0	2.89	120.4	6.15	256.1
oilseeds							212.49		61.01	
ginseng, sod & nursery										
other field crops										
soybeans	74.82	35.2	98.40	46.3	212.50	100.0	229.87	108.2	117.54	55.3
tobacco	242.19	84.6	175.63	61.4	286.13	100.0	239.85	83.8	161.37	56.4
vegetables			76.02	106.6	71.31	100.0	82.23	115.3	94.80	132.9
AVERAGE	88.45	64.0	97.37	70.4	138.22	100.0	135.43	98.0	125.68	90.9

Table 24: Risk per kg of pesticide using the PSL for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%
corn	28.59	101.0	28.55	100.8	28.31	100.0	28.23	99.7	28.24	99.8
field beans	26.45	96.9	26.90	98.6	27.29	100.0	27.40	100.4	26.35	96.6
fruits	36.23	103.4	35.28	100.6	35.05	100.0	35.85	102.3	34.20	97.6
grains	23.61	101.6	22.70	97.7	23.23	100.0	23.85	102.7	22.95	98.8
hay & pasture	25.74	105.3	25.94	106.1	24.44	100.0	19.30	79.0	16.45	67.3
oilseeds							29.66		33.83	
ginseng, sod & nursery										
other field crops									35.85	
soybeans	27.93	102.1	27.26	99.6	27.36	100.0	27.47	100.4	25.87	94.6
tobacco	32.37	102.1	32.16	101.4	31.71	100.0	31.55	99.5	31.23	98.5
vegetables			36.07	101.4	35.57	100.0	33.72	94.8	34.61	97.3
AVERAGE	30.75	104.6	29.77	101.3	29.39	100.0	29.01	98.7	28.55	97.2

Table 25: Risk per ha of crop area using the PSL for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%
corn	71.95	70.4	87.97	86.1	102.22	100.0	85.08	83.2	84.15	82.3
field beans	53.73	107.4	65.64	131.2	50.04	100.0	113.06	225.9	70.88	141.6
fruits	1155.37	166.4	434.01	62.5	694.43	100.0	738.21	106.3	708.87	102.1
grains	9.49	92.5	7.51	73.2	10.26	100.0	14.00	136.4	16.78	163.5
hay & pasture	0.38	106.6	0.25	71.3	0.35	100.0	0.58	164.1	0.99	279.4
oilseeds							48.73		15.24	
ginseng, sod & nursery										
other field crops										
soybeans	52.32	54.3	49.80	51.7	96.35	100.0	90.04	93.5	42.74	44.4
tobacco	1365.31	104.4	941.16	72.0	1307.27	100.0	1032.80	79.0	628.56	48.1
vegetables			214.29	123.4	173.71	100.0	201.19	115.8	204.51	117.7
AVERAGE	41.75	72.7	43.98	76.6	57.40	100.0	51.19	89.2	44.11	76.9

Table 26: Risk per tonne of crop production using the PSL for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%
corn	13.33	75.6	17.25	97.9	17.62	100.0	16.05	91.1	12.49	70.8
field beans	36.62	88.0	57.49	138.2	41.59	100.0	95.08	228.6	39.54	95.1
fruits	175.83	262.9	45.17	67.6	66.87	100.0	73.60	110.1	74.04	110.7
grains	4.02	104.0	2.97	76.9	3.87	100.0	5.10	131.9	5.79	149.6
hay & pasture	0.12	128.6	0.07	78.9	0.09	100.0	0.13	143.0	0.19	206.9
oilseeds							37.70		9.56	
ginseng, sod & nursery										
other field crops										
soybeans	25.10	51.6	27.56	56.7	48.60	100.0	41.50	85.4	16.88	34.7
tobacco	548.22	102.7	382.91	71.8	533.66	100.0	407.42	76.3	247.96	46.5
vegetables			10.76	115.8	9.30	100.0	8.95	96.3	9.55	102.7
AVERAGE	11.49	84.6	11.36	83.7	13.58	100.0	12.06	88.8	8.92	65.7

Table 27: Risk per dollar of crop value using the PSL for agricultural crops in the Province of Ontario from 1973 to 2003

CROP	1973	73%	1978	78%	1983	83%	1988	88%	1993	93%	19
corn	54.62	49.2	98.50	88.7	111.00	100.0	137.75	124.1	141.95	127.9	1
field beans	25.09	37.8	93.10	140.1	66.44	100.0	162.48	244.5	118.53	178.4	
fruits	285.83	159.6	90.46	50.5	179.06	100.0	208.88	116.7	233.73	130.5	1
grains	17.05	63.0	18.42	68.1	27.07	100.0	42.13	155.6	73.76	272.5	
hay & pasture	1.96	120.3	0.92	56.3	1.63	100.0	1.88	115.4	4.09	250.2	
oilseeds							142.60		46.53		
ginseng, sod & nursery											
other field crops											
soybeans	48.74	34.4	61.97	43.7	141.81	100.0	163.82	115.5	83.05	58.6	
tobacco	128.34	86.4	92.84	62.5	148.49	100.0	124.68	84.0	83.27	56.1	
vegetables			58.07	108.7	53.43	100.0	60.74	113.7	66.74	124.9	
AVERAGE	56.09	62.0	64.03	70.8	90.39	100.0	94.11	104.1	88.43	97.8	

Table 28: Change in use (number and amount) of the 24 "high risk" pesticides between 1983 and 2003 using the three risk scoring systems. The "high risk" pesticides for each scoring system are presented in Table 12.

	EIQ		EHI		PSL	
	1983	**2003**	**1983**	**2003**	**1983**	**2003**
Number of pesticides in the highest scoring 24	17	10	18	7	17	13
Amount (kg)	253880	67125	416440	16165	229410	122539

Table 29: The impact of changing the plant surface half-life score of glyphosate on the risk assessment using the EIQ.

	plant surface half-life = 3			plant surface half-life = 1		
CROP	**1983**	**2003**	**03%**	**1983**	**2003**	**03%**
corn	97.00	35.36	36.5	96.95	33.61	34.7
field beans	0.82	1.22	149.0	0.80	0.89	110.5
fruits	19.26	6.96	36.2	19.25	6.91	35.9
grains	7.88	10.82	137.3	7.35	9.38	127.5
hay & pasture	0.40	0.52	128.9	0.37	0.28	76.3
oilseeds		0.32			0.19	
ginseng, sod & nursery		0.89			0.70	
other field crops		0.16			0.09	
soybeans	20.88	28.41	136.1	20.48	16.34	79.8
tobacco	57.86	12.08	20.9	57.85	12.07	20.9
vegetables	9.07	5.65	62.3	9.06	5.51	60.8
TOTAL	213.17	102.38	48.0	212.11	85.97	40.5