Integrated Pest Management Implementation Plan for the Nebraska Cattle Industry

Rita Schenck
Douglas Huizenga
Institute for Environmental Research and Education
December 2000

Executive Summary

Substantial work on Integrated Pest Management in Livestock has provided technical resources for managing pests on livestock. However, up to now little has been done to develop a program that supports the adoption of IPM practices in this important agricultural sector. This report describes an IPM plan for the cattle industry in Nebraska. It is based on the use of a comprehensive environmental management system that includes conformance to international standards and the use of life cycle assessment to provide ecolabels.

The elements of the IPM plan are:

- Characterization of the Cattle industry in Nebraska. 4 million cattle are slaughtered in Nebraska every year; over 70% of the landmass is devoted directly or indirectly to raising cattle.
- Development of a network of technical support for IPM implementation, through the University of Nebraska/cooperative extension program.
- Enrollment of 10 demonstration farms
- Communication through:
  - Internet dissemination
  - Use of farms/ranches as demonstrations in the cooperative extension service farm days
  - Publication in the Nebraska Cattlemen's publications and elsewhere.
- Tracking pesticide impacts using a life-cycle indicator (developed in this report)
- Identifying resources to develop a baseline of the current usage of pesticides and IPM practices in Nebraska cattle operations

The intent of this plan is to provide a management framework that will encourage producers to employ IPM practices in the context of a holistic environmental management program.

A science-based approach to measuring progress in reducing pesticide impacts is the key to the successes of this program. This plan introduces a Toxic Unit approach to measuring pesticide impacts which is based on the toxicity, persistence and fate of pesticides in the environment. Demonstration farms are expected to achieve a 50% reduction in Toxic Units within 10 years, and the industry as a whole to reduce toxic units by 10% in the same time period.

Table of Contents

Table of Tables

Introduction

The primary goal of IPM (Integrated Pest Management) is to reduce the non-target effects of chemical pesticides without causing economic losses. In the past, much of the IPM efforts of have been focused on crops such as corn or cotton, because these crops are typically grown with large pesticide inputs. Though significant research has been performed on IPM in livestock[i], to our knowledge, no active IPM implementation plan has focused on this important agricultural sector.

This document describes an IPM implementation plan for the Cattle industry (Beef and Dairy) in Nebraska. It was based on extensive discussion with IPM experts and other interested parties in the State of Nebraska, as well as with producers. This work was funded by a grant from American Farmland Trust.

Early on in our discussions with stakeholders and producers, it became clear that for IPM to be sucessful there would have to be a management system in place that rewarded producers implementing IPM, and that that reward should be based on science based measurements of progress. In addition, it was clear that although there is a great deal of information in the form of pamphlets and on-line reports on IPM methods, these informational channels are not the best ones to get the producer to change his or her mind about how to manage their operations. Different methods, ones that would get to the "café counter" discussion level were needed.

Based on our discussions, and particularly based on the explicit request of producers, it was decided that the IERE ecolabel program should be the basis of the program. The power of the market (thought he ecolabel) can be used to influence farmers to adopt IPM practices. Early adopters of this program would provide model farms that could be used as a basis of the communications program.

One of the values of this approach is that the ecolabel program can be applied anywhere in the world, not just in Nebraska. Further, the system is flexible enough to be applicable to all agricultural products, not only to the cattle industry.

IPM Implementation Plan for Cattle in Nebraska

Based on the discussion held throughout the year with producers and IPM specialists in the state, we have developed a plan for IPM implementation for Cattle in the State. The at plan includes the following elements:

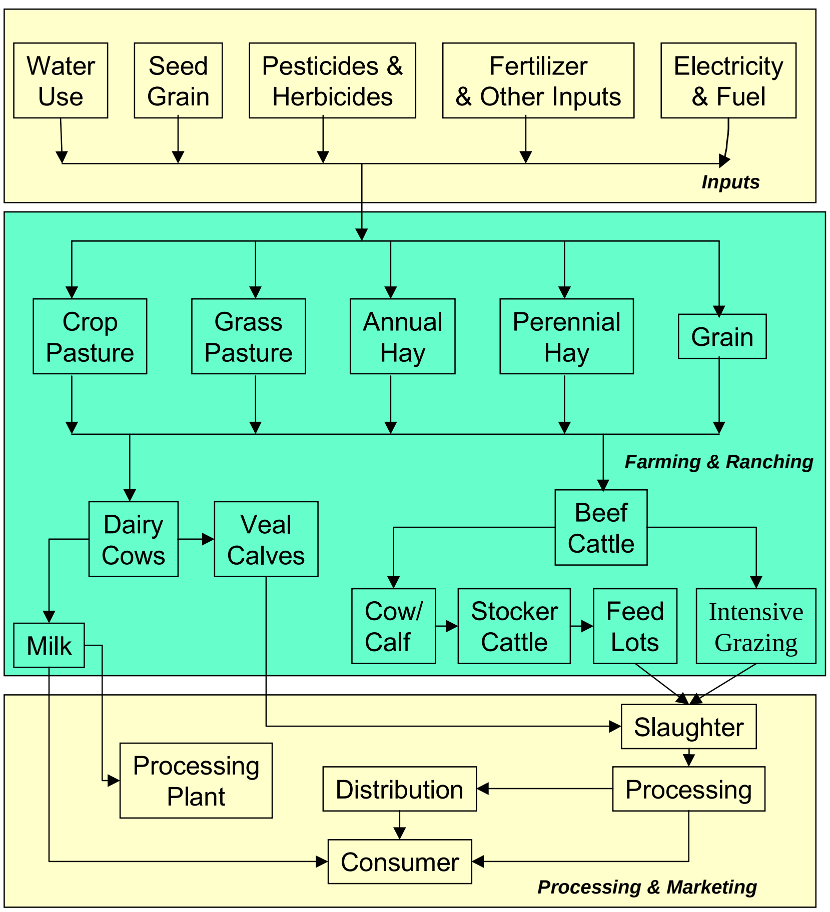
1. Characterize the Cattle industry in Nebraska
2. Develop a network of technical support for IPM implementation
3. Enroll 10 farmers in the IERE sustainable agriculture and ecolabel program
4. Communicate the activities, progress and measurements of these 10 farms through:
   - Internet dissemination

- Use of farms as demonstrations in the cooperative extension service farm days
- Publication in the Nebraska Cattlemen's publications
5. Track pesticide impacts using the indicators developed here.
6. Identify resources to develop a baseline of the current usage of pesticides and IPM practices in Nebraska cattle operations

The Nebraska Cattle Industry

The lifecycle of beef cattle in Nebraska and elsewhere in the US can be described as follows. Cattle are inseminated either through artificial insemination or naturally, and pregnant cows are put to graze either in pasture or rangeland. Once calves are born, they stay with their mothers until weaned, generally at about 6 months. Cow-calf pairs are generally also kept on pasture or rangeland. After weaning, beef cattle may remain on pasture for some months, or they may go directly to feed lots. Nearly all beef cattle are placed in feed lots by 12 months of age. For the next six to nine months, approximately, the cattle are fed a ration, which is approximately 85% corn, the remainder hay, and other feedstuffs. Age at slaughter is typically 14-18 months.

Figure 1 Nebraska Cattle Life Cycle



The Dairy cow has a similar lifecycle, but on average dairy cows spend less time on pasture or rangeland. The majority of dairy cows are bred through artificial insemination. Calves are typically weaned from the cow within 48 hours of birth, and fed on milk replacement. This allows the farmer to gain the economic advantage of the milk production that would otherwise go to feeding the calf. Males are typically sold within the first six months of life to produce veal or to be grown on feedlots for beef. Females are weaned off the milk replacement to pasturage or rangeland. Heifers are inseminated at 14-16 months of age, and remain on pasture or rangeland until the birth of the calf nine months later. Within a few weeks cows are typically confined to barns, and fed on a ration that resembles the beef feedlot ration.

Milk cows are typically milked for 10 months, then put into a feedlot and fed on a low grain ration to dry off until the next calf is born, when the milking confinement begins again. Most dairy cattle are treated with growth hormone that reduces their lifespan to less than five years (2-3 lactation cycles).

Some dairies are operated on a seasonal grass system without hormones. Here the cows are maintained on pasture, often with corn supplementation to maintain milk volumes. Dairy cows maintained in this fashion typically live for 8 lactation cycles.

Every year in the State of Nebraska 1.8 million calves are born, 4.4 million move through feed lots, and 7.3 million head are slaughtered. This represents about 20 percent of the total beef production in the country. By comparison, there are about 72,000 milk cows in Nebraska.

There are 23,800 farms in Nebraska with beef cow operations: the average herd size is 82 cows. There are 5,700 cattle feeding operations, with an average size under 850 head. There are 665 feeding operations that produce more than 1000 head per year, and this represents 95 percent of the cattle feedlot production.

Nebraska contains approximately 30 federally inspected slaughter facilities for cattle. However, the majority of the slaughter capacity in Nebraska (three very large facilities) is owned by IBP. As a consequence, IBP sets the price for cattle in the state.

Cattle raising is the cornerstone of the Nebraska economy, and is estimated to bring $11.5 Billion annually to the Nebraska Economy from the $4-5 Billion in cattle sales[ii].

The Use of Pesticides in the Nebraska Cattle Industry

The majority of the pesticide use over the lifecycle of cattle comes from their use in the production of corn and other feedstuffs. Very little pesticide is used on pasturage or rangeland. Moreover, the majority of the cattle in feedlots in the state are imported from other states. There is a significant use of pesticides during the confinement portions of the cattle life cycle, and our preliminary efforts for cattle IPM will focus primarily on this aspect of pest management.

Pesticide use in livestock confinement is primarily used to control flies. The fly lifecycle includes a free-living stage, a stage either attached to or inside the animal, and a stage in animal manure. Some of the pesticide application targets the fly life stage that is an internal parasite and applied internally, while others are applied as a spray or dip, as injection or as a self-application system. The tables below show the data on pesticide use in confinement operations. They are derived from USDA surveys[iii], of the North-Central Region, of which Nebraska is a part.

Table 1 North Central Beef Cattle Insecticide Use, 1999

North-Central Beef Cattle Application, 1999			
Insecticides	(000#'s)	gm/head/ application	Gm/head /year
Carbaryl	83.6	25.3	100.5
Chlorpyrifos	2.8	4.7	5.8
Coumaphos	20.6	2.9	8.1
Cyfluthrin	78.9	1.1	1.2
Cypermethrin	0.4	1.1	1.1
Diazinon	17.3	12.6	15.1
Dichlorvos	88.9	2.9	3.5
Dipropyl isocinchom.	*	2.1	4.9
Doramectin	1.5	0.2	0.2
Eprinomectin	0.3	0.1	0.1
Ethion	4.8	4.7	7.5
Famphur	72.9	13.6	14.2
Fenthion	14.2	6.3	6.9
Fenvalerate	0.5	0.2	1.1
Fencythrinate	*	1.2	1.2
Ivermectin	3.6	0.2	0.2
Lambda-cyhalothrin	*	1	1
Malathion	30.8	21.3	46.1
Methoprene	2.1	0.1	0.7
Methoxychlor	*		15.2
Moxidectin	0.4	0.1	0.1
N-octy-bicycloheptene	1.7	0.9	2
Permethrin	67.6	3.7	8.1
Petroleum Distillate	38.7	34.3	68.6
Phosmet	*	12.7	40
Piperonyl butoxide	128.4	3.7	11.4
Pirimiphos-methyl	2.1	2.7	3
Pyrethrins	20.1	0.9	11.7
Tetrachlorvinphos	182.3	51.5	87.9
Trichlorphon	*	6.8	7.2
Xylene	255.2	47.3	49.4
Zeta-cypermethrin	*	1.1	1.1
Total Insecticides	786.2		

Of the total chemical applications made to beef cattle in 1999, the method of application was 39 percent by pour-on, 18 percent by spray, and 11 percent by injectable shot. All other methods (dip, dust, mineral block, rubbing device, pill, ear tags, and other) accounted for the remaining 32 percent of applications. Of the total chemical applications made to dairy cattle in 1999, the method of application was 65 percent by spray, 13 percent by pour-on, and 10 percent by both rubbing device and dust. All other methods (dip, mineral block, injectable shots, pill, ear tags, and other) accounted for the remaining 2 percent of applications.

Table 2 North Central Dairy Insecticide Use, 1999

North-Central Dairy Cattle Application, 1999			
Insecticides	(000#'s)	gm/head/ application	Gm/head /year
Coumaphos	1.4	2.7	7.5
Cyfluthrin	77.1	31.1	160.5
Dichlorvos	78.7	7.2	183.2
Doramectin	*	0.2	0.2
Eprinomectin	*	0.2	0.3
Famphur	*	12	16.1
Fenthion	*	7.8	7.8
Ivermectin	0.3	0.3	0.4
Malathion	*	5.5	27.2
Methoprene	1.9	1.2	30.9
N-octy-bicycloheptene	*	0.6	4.1
Permethrin	13.2	2.6	19.8
Piperonyl butoxide	*	2.3	62.1
Pyrethrins	*	0.4	10.6
Tetrachlorvinphos	1.5	1.0	9.2
Xylene	*	42.1	56.2
Total Insecticides	378.1		

Insecticides are also applied to buildings

Table 3 North Central Cattle Buildings and Structures Pesticide Use, 1999

Cattle Buildings and Structures: 1999 (000#'s)		
Insecticides	**Beef**	**Dairy**
Cyfluthrin	0.1	9.0
Dichlorvos	12.7	1.7
Dimethoate	0	75.7
N-octyl-bicycloheptane	0	0.1
Permethrin	0.8	0.9
Piperonyl butoxide	1.1	17.0
Pyrethrins	0.2	2.9
Total Insecticides	39.1*	120.0*

There are three basic opportunities to reduce the use of pesticides in cattle.

1. Reduce or eliminate the time spent in confinement (this also reduces the corn-related pesticide use).
2. Manage the manure in confinement systems, removing it at least daily
3. Use self-application rather than ingested, sprayed or injected insecticides.

The Technical Network

Nebraska is rich in human resources with expertise on the topic of IPM. The cooperative extension service and the University of Nebraska support a wide variety of research and outreach services to assist farmers in adoption IPM practices. The following individuals have agreed to assist this effort by working with farmers, by using the 10 model farms in the program for field days, and by developing publications that will provide technical resources to them. All of them are supported either by the University or the Cooperative Extension Service or both.

Table 4 Technical Network

Individual	Affiliation and Primary Area of Expertise
Jack Campbell	U of N Livestock IPM
Bruce Anderson	U of N Grazing Systems
Terry Gompert	Extension Grazing Systems
Kieth Jarvey	U of N Crop IPM

All of these individuals are fully funded for these activities and view the IPM approach as natural extension of their responsibilities.

Pilot Farms and Goals

Pilot farms are the pivot of this IPM implementation plan. Producers operating on these farms or ranches are committed to reducing pesticide impact on their farms and sharing information on their progress with other producers. The goal set for these pilot farms is a 50% reduction of pesticide impact over the national average within 10 years. The goal for the Nebraska cattle industry is a10% reduction over the same time period.

The following is a list of the farms that have so far volunteered to pilot the program.

Table 5 Pilot Farms

Farm	Location	Type	Acreage
Loup Valley	Callaway	Dairy	370
Triangle H	Elsie	Cattle	1600
Jenkins Ranch	Callaway	Cattle	4910
Kelly Brauns	Knox County	Dairy	360

The IERE Ecolabel System

IERE has developed an ecolabel system based on the ISO 14000 standards. This program requires farmers to develop and implement an on-farm environmental management system, and measures performance using life cycle assessment. Farms participating in the program are showcased on the IERE website.

The use of life cycle assessment assures that the evaluation of the environmental performance is holistic, science-based and transparent. Life cycle assessment is a method of evaluating the environmental impacts of products and services over the entire life cycle of the product (*i.e*., from cradle to grave). A life cycle impact assessment is holistic in that it is based on a comprehensive list of impact categories, or environmental issues of concern. Inventories of emissions and resource use are used as inputs to models, which provide impact indicators for each impact category. Appendices A and B document the program in full.

The ecolabel program is an effective spur to improved environmental performance because it includes environmental disclosure, and also because products with ecolabels have been shown to garner a 40 to 200% price differential at retail.

Communication Plan

It was the consensus of the producers working on the program that effective communication would require reaching the level of the café table discussion. Although extensive information on IPM is available through the Internet and paper publications, it would require face-to-face discussions to get others beyond the pilot farms to implement the plan.

We therefore developed a plan that would be primarily driven by word-of-mouth, with backup in written formats. The primary outreach method will be through the extension service's field days. This medium allows farmers to see how their peers are farming and to get practical ideas that they can implement themselves.

IERE will be providing information about measuring pesticide impacts and the recognition that is provided by ecolabels and environmental management systems. Our technical resources will provide specific information about IPM practices, including scouting methods, financial thresholds for actions and actions that can be taken to reduce the reliance on pesticides.

Approximately, quarterly, IERE will publish information about the program and its progress designed to advertise the advantages of IPM through the Nebraska Cattlemen's weekly publication. Additional publications will be made on the IERE website, in the Stockman Grass Farmer, and other media.

Tracking Pesticide Impact Using an LCA Indicator of Pesticide Use

In order to measure the effectiveness of IPM, it is necessary to evaluate not only management decisions (e.g., adoption of management practices), but also the reduction of environmental impacts due to pesticide use. LCA is an ideal framework for developing such an indicator. Life cycle indicators are not intended to be actual measures of environmental impacts. However, they are based on the environmental mechanism[1], and are intended to be simplifications that are believed to correlate to environmental effects.

When pesticides are used, a certain proportion acts locally where applied, and the rest disperses through soil, water and air. The rate and extent of dispersion is quite different in these different environmental compartments. Pesticides that disperse into groundwater remain more-or-less locally, depending on the characteristic flows of aquifers. Aquifer movement is measured in meters per year. Pesticides which disperse in surface water move hundreds to thousands of miles in streams lakes and estuaries, with flow rates of meters per minute. Air dispersion can be global and is measured in meters per second.

As pesticides are being dispersed, they are also undergoing transformation and degradation. The half life of pesticides is very variable, ranging from a few days to years. The daughter products of pesticides can have quite different chemical properties and may be more or less toxic than the pesticide itself. Different pesticides also have very different toxicities.

The pool of pesticides in the surface water and in the air are continually exchanging through evaporation and precipitation. The residence time in the air is generally short, because the pesticides (and daughter products) precipitate through natural processes. Persistent pesticides have been shown to go through the evaporation/precipitation cycle many times, and tend to accumulate in polar climates, where the evaporative potential is small. For most pesticides, the majority of the toxic effects are derived through exposure in the water. Aquatic animals are exposed more than are terrestrial animals, because they breathe the water, and thus are exposed to much more contaminant per day than are the terrestrial animals which only drink it. Low levels of some pesticides are concentrated through the aquatic food chain until body burdens to aquatic life exceeds an effects level.

In summary, water is the primary vector for pesticide toxicity. The toxic effects of pesticides in groundwater are a local problem, while pesticides leaving a location in surface air or water have regional or global impacts. Different pesticides have different toxicities, half-lives and daughter products, and therefore different lengths of time during which they pose a hazard.

The best indicators of pesticide impacts must accommodate the characteristics of pesticide behavior in the environment as well as its toxicity. At the same time, the indicator must be relatively simple to calculate, and be based on readily available information (preferably published information).

As noted above, indicators need not measure actual environmental impacts. However, users must be confident that the indicator correlates well with those impacts. To support

[1] ISO 14042: Environmental Management Systems: Life Cycle Assessment: Life Cycle Impact Assessment.

this goal, we have chosen an approach that is based on first principles. It is based on a toxic unit approach. The indicator includes toxicity and persistence and incorporates the losses of the pesticide from the fields to which it is applied. While the indicator is based on first principles, it also resembles the toxicological indicators developed by other researchers[iv]

We calculate toxic units as:

$$TU = M_0 \times L \times \frac{1}{NOEL}$$

Where:

TU = Toxic Units
M_0 = Mass (escaped per year)
L = Integrated lifetime, in years;
$NOEL$ = No observable effects level in water (mass per volume)

Calculating the mass of pesticides escaping is based on sophisticated numerical simulation models. A great deal of work has been done over the last 20 years to develop such models, and that work continues. In considering the motion of pesticides, we have made some assumptions. Specifically, we assume that:

- Our field is a box that has sides equivalent to the field edge,
    - the top is at the crop canopy, and
    - the bottom is the water table.
- Pesticides leave the field
    - during application through drift, and
    - after application via water transport through or over the soil and
    - via air transport as pesticides are evaporated from the soils.
- Only the pesticides escaping this box are considered to have an effect.

Many models have been developed to evaluate pesticides applied to row crops. A survey of these models and our selection of the most useful to our Toxic Unit approach are in the next section. Regardless of the model employed, it must provide an estimate of M_0, the amount of pesticide escaping the field, in order to be useful to the TU indicator calculation.

The next variable in the TU equation, lifetime is used to evaluate the persistence of the pesticide in the environment. It represents the total lifetime of the pesticide in the environment. The model assumes that the pesticide degrades exponentially in the environment, following the equation

$$M_t = M_o e^{-kt}$$

Where:

M_t is the mass at time t,

M_0 is the mass at time 0,

And k is the rate constant that describes the removal, in units of inverse time.

Evaluating at t equals infinity, and integrating the result over the entire time, t, we obtain:

$$\int_0^\infty M_t = \frac{M_0}{k}$$

Where:

M = Mass
And the lifetime is the inverse of the degradation constant, k, or:

$$L = \frac{1}{k}$$

The half-life, λ is related to the lifetime as:

$$-\ln 0.5 \times L = \lambda$$

Toxicity is the last element of the TU equation. We have used the No Observable Effect Level (NOEL) as our toxicological constant because it provides an accurate measure of the toxicity of a substance. NOEL's are measured in laboratory experiments. Where possible, we have used published values for NOELS of aquatic organisms. Where these were not available, we used LC_{50}s (The concentration lethal to one-half of test organisms). In many cases NOEL's are only available for rodents drinking contaminated water or food. These figures are usually provided in units of mg/kg/day. In this case, we have converted the NOEL's to water concentrations using a conversion factor of 35 kg-days/liter. This provides units of mg/L. Regardless of the source of the NOEL, we have employed the most sensitive organism's NOEL or LC_{50}, thus providing a measure of safety for the ecosystem.

The inverse of the NOEL is used in calculating the toxic units because the more toxic the substance, the lower the NOEL. Using the inverse provides a scale where higher values indicate more environmental impact. Toxic units are measured in equivalent volumes, and can be thought of as the amount of water contaminated by the use of pesticides. More precisely, they represent the maximum amount of water that could be contaminated at levels exceeding the NOEL.

As a life cycle indicator of pesticide effects, toxic units can be used directly, assuming that 100 percent of the pesticide applied escapes to the environment (i.e., escaped mass = applied mass). However, this assumption overestimates the adverse effects of pesticide use, and should only be viewed as a screening tool. Calculating the amount of pesticide that escapes the field provides a better view of the effects of pesticide use.

The focus of this IPM plan on the application of pesticides on animals held in confinement and on the structures in which they reside provides a particular challenge, because there are few models of the environmental fate and transport of pesticides applied in this manner. For a life cycle assessment indicator, it is essential that the same model approach be applied to all the pesticide effects, not only those that are the focus of the IPM plan.

Consider, for example, the use of vermicides. Most vermicides are ingested, and they work on the fly life cycle stage in the intestine. We can assume that the majority of the pesticide (perhaps 90% or more) passes through the animal and is deposited as fecal material. Once it leaves the animal, its dispersion can be modeled using a field application model. Several researchers have addressed the problem of fate and transport for the vermicide Ivermectin.[v]

In another example, where pesticide is applied by spray, dip or poured directly to the skin, a certain percentage of the pesticide will be absorbed through the skin, while the remainder will either be removed through rain or through evaporation. It is difficult to evaluate what percentage of the pesticide is dispersed through the soil or through the air and few studies have addressed this issue.

Where pesticides are applied to buildings, they may be applied either to the interior or to the exterior. Exterior application may be dispersed through rain out and evaporation, and in the interior, dispersal will occur only through evaporative processes. At the moment, we have no information vis-à-vis the losses of pesticides applied to buildings. We therefore are assuming that all of the pesticides that are applied evaporate or degrade. This permits a simple calculation of the toxic units in the North Central Region

Table 6 Toxic Unit Calculation

Cattle Buildings and Structures: 1999						
Insecticides	**NOEL (mg/L)**	**Lifetime (years)**	**Insecticides Applied, (000#)**		**Toxic Units, m^3 (000's)**	
			Beef	**Dairy**	**Beef**	**Dairy**
Cyfluthrin	0.00000014	0.119	0.1	9	38,453,046	3,460,774,131
Dichlorvos	0.004	0.028	12.7	1.7	39,882	5,339
Dimethoate	2.1	0.028	0	75.7	0	453
N-octyl-bicycloheptane[2]	N/A	0	0	0.1	N/A	N/A
Permethrin	0.0018	0.119	0.8	0.9	23,926	26,917
Piperonyl butoxide[2]	N/A	-	1.1	17	N/A	N/A
Pyrethrins	0.0018	0.140	0.2	2.9	7,051	102,243
Total Insecticides	N/A	N/A	39.1	120.0*	N/A	N/A

As can be seen, the toxic units for buildings are totally dominated by a single insecticide, Cyfluthrin. Its application to cattle buildings leads to a potential 3,500 cubic kilometers of water being contaminated at levels that cause adverse effects. This pesticide is extraordinarily toxic to the aquatic invertebrate *Daphnia magna* as well as to shrimp and oysters. These preliminary results indicate that focusing on reducing this single pesticide may yield substantial results in a very short time period if producers simply switch to other products.

The Toxic Unit approach, with an input term allows great flexibility and permits us to add up the effects of the different pesticides and pesticide application regimes. This has not been done in the table above because so many pesticides are not reported in the NAAS reports.

Fate and Transport of the Pesticide in the Environment

As noted above, dispersion models are in active development, becoming more accurate and easier to use over time. Our toxic unit indicator is very flexible in that it permits continuous improvement, as models become more sophisticated. As noted above, as a screening methodology, one can assume that the total amount applied escapes into the environment. For some pesticides and applications this is a good assumption. However, for the majority it is not.

We have evaluated the current fate and transport models available to calculate the amount of pesticide that escapes our "box." Most of the models were developed for pesticide application for row crops. We developed criteria to evaluate the applicability of the models to support the toxic unit model. They are shown below.

[2] Synergists, NOEL's Not available because they function to increase the activity of other agents.

Criteria for Model Selection

1. The model must be able to calculate the amount of pesticide leaving the field by a particular pathway.
2. Model inputs must be site specific: soil type, soil organic matter content, climate, tillage practices, method of pesticide application
3. The model must be publicly available and well supported.
4. Model input parameters must be readily obtained from the site specific information combined with publicly available data sources.
5. Model verification under a variety of field conditions must be available in the open literature.

As some authors have noted[vi], there is no one model that incorporates all dispersion pathways. This is not a reason to despair of using dispersion models however. It simply means that the different pathways of dispersion must be modeled separately and then added together to calculate the total mass that escapes the field. Dispersion models exist for runoff and leaching, volatilization, and spray drift: all the possible pathways for pesticide losses except wind erosion. Wind erosion is generally assumed to be a small component of pesticide dispersion, and no generally accepted model for this component is currently in use.

Runoff and leaching

Runoff and leaching models estimate the amount of pesticide that leaves the field either through leaching to the groundwater or by running off the surface of the field. The models fall into two groups: screening models and simulation models.

Screening Models

Screening models generally rank the pesticides for potential impact to surface and ground water but do not calculate the actual amount of pesticide leaving the field. A pesticide that that is very water soluble and has a long half-life is predicted to leave the field when it rains. A pesticide that not water soluble and has a short half-life is predicted to have low impact on runoff or groundwater. Screening models are essentially scoring systems, not calculation systems. They do not take into account the site-specific nature oils agricultural practices and application methods. Thus they fail Criteria 1 and 2 above. They nevertheless are useful ways of looking at worst-case pesticide risks. When pesticides "pass" a screening program, it is assumed that environmental risks are minimal. It is not necessary to perform a more complicated calculation of dispersion, at least for regulatory purposes. Below is a description of some of the more common screening models.

SCI-GROW (Screening Concentration in Ground Water)

SCI-GROW is an empirical model that estimates worst-case pesticide concentrations in groundwater. It calculates a worst case concentration of pesticides in groundwater for calculation of potential health risks from drinking groundwater. It is applicable to areas where the groundwater is extremely vulnerable to contamination.

SPISP (Soil Pesticide Interaction Screening Procedure)

is a rating system that uses soil and pesticide properties to assess pesticide potential for leaching and runoff. No climate data is introduced in the rating. The soil/pesticide combinations are rated but no concentration estimates are produced.

WIN-PST (Windows Pesticide Screening Tool)

WIN-PST uses the SPISP procedure with field management input and can include toxicity in the analysis. Hazard ratings are produced by combining pesticide loss categories with toxicity.

CMLS (Soil Pesticide Interaction Screening Procedure)

CMLS can be used to model the downward movement of pesticides due to movement of water down into the soil. The model produces the depth concentration profile of the pesticide and predicts how the profile evolves with time. The amount of pesticide leached into groundwater is not estimated.

Simulation Models

The Toxic Unit indicator requires estimates of the quantity of pesticide leaving the field. Models that can produce these estimates are much more complicated than the screening models and require many more input parameters. Two models are particularly well suited to field level modeling: the pesticide root zone (PRZM) model and groundwater loading effects of agricultural management systems (GLEAMS) model[vii]. Conceptually, these two models are similar. Both approach hydrology and erosion by using Soil Conservation Service curve number technique and the Universal Soil Loss Equation. Both can predict pesticide loss in runoff and leaching. Both have been tested under a variety of conditions (a recent summary is given in: Jones and Russell (2000)).

PATRIOT (Pesticide Assessment Tool for Rating Investigations of Transport), Advanced screening model

PATRIOT can provide a quick analysis of groundwater vulnerability to pesticides. It combines PRZM2 with soil, cropping, and rainfall databases. Analyses can be performed over a range of scales from the county or single USGS Hydrologic Cataloging Unit to regional scales. The model is not applicable to the field scale calculations.

PRIZM 3 (Pesticide Root Zone Model, Version 3)

PRZM3 is a one-dimensional model that predicts pesticide transport and transformation above the water table. It consists of two linked modules - PRZM to handle the root zone and VADOFT to handle the unsaturated zone below the root zone down to the water table. The model can simulate multiple pesticides or parent/daughter relationships, is site-specific, and accommodates cultural practices. PRIZM-3 is well supported by the U.S. EPA. It meets all the model selection criteria.

GLEAMS (Groundwater Loading Effects of Agricultural Management Systems)

GLEAMS is a field scale model that simulates sediment and pesticide movement at the edge of a field and pesticide loss at the bottom of the root zone. It serves as the calculational model for risk analysis for the National Agricultural Pesticide Risk Analysis (NAPRA) model. This model does not consider the unsaturated zone below the root zone. Application to a situation where there is a large unsaturated zone will lead to an over-prediction of the amount of pesticide getting into groundwater. The model does not conveniently include parent/daughter relationships.

GLEAMS is well supported by the USDA-ARS.

Volatilization

Models for pesticide volatilization range widely in their sophistication. Correlation equations derived from measurements of pesticide volatilization soon after application can be used to estimate pesticide volatilization based on vapor pressure, K_{oc}, and water solubility (Woodrow et al., 1997)[viii]. Volatilization from plant surfaces soon after application correlates well with vapor pressure alone.

Pesticide volatilization both within the soil and from the surface of the field is an integral part of the PRZM3 model. GLEAMS does not include pesticide volatilization.

The pesticide emission model (PEM), a product of ORTECH International (Mississauga, Ontario), was used to calculate hourly emissions of Atrazine emission over much of North America for the Lake Michigan mass balance study[ix]. This model uses a time step of less than one hour. In some cases, PEM has calculated that 50% of pesticides applied are volatilized into the air. There are suggestions that that about 95% of the atrazine in Lake Superior is derived from atmospheric inputs[x]. The PEM model appears to be of high quality, but its coding is not yet available to the public, thus it fails of the basis of Criterion 3.

Spray Drift

Two older drift models are FSCBG (Forest Service Cramer-Berry-Grimm) and AgDISP. The newer model AgDRIFT appears to be positioned to replace the older models. AgDRIFT is the primary model recommended by the FIFRA Exposure Model Validation Task Force for this transport mechanism[xi]. This model uses the application mechanism information to model the proportion of the applied pesticide that escapes the field. In a worst-case assessment, about 2% of the pesticide applied to a field is lost through spray drift. The equations imbedded in AgDRIFT are derived from field studies.

Selection of Models

In summary, It is possible to calculate all the escaping mass of pesticides from fields using only two models: PRZM and AgDRIFT. These two programs are well supported and free to the user. They are based on publicly available information about soils and meteorology, and PRIZM is the preferred programs for pesticide registration in the United States. They have been field validated, and that validation analysis is publicly available. They meet all the selection criteria and therefore appear to be the best choices at this time. The table below shows the models evaluated for this study and how they performed against selection criteria.

We can compare the Toxic Unit approach against selection criteria developed for the EU[xii]. Of the six criteria suggested by Reus et al., the Toxic Unit approach meets all except the second: that the model should give information about different environmental risks. In this case the authors mean that different protection subjects should be identified separately. Our model does not do this. It is worth noting that Reus et al recognize that such an approach is likely to be confusing to the user.

At the moment, we are not willing to provide separate mechanisms for humans, animals and aquatic subjects for several reasons. First, the vast majority of toxicological information is derived from studies with rodents or aquatic organisms. Identifying humans as a protection subject (the most common use of this data) seems to us to be misleading at best. Second, it seems to us to be of little value to separate different environmental compartments in the case of pesticide toxicity when the majority of the toxic effects (as noted above) derive from water-based toxicity. Finally, we agree with

Reus et al. That separation among many protection subjects can be confusing to the user. The point of a life cycle assessment is not to account for every possible endpoint, but to provide a limited number of indicators that we are confident correlate to the impacts.

The toxic unit approach is simple while being scientifically rigorous, and it provides direct comparisons among many different pesticides and applications, giving farmers a clear signpost for how they can improve their pest management programs to better protect the environment.

We wish to thank AFT and the US EPA for their support of this work.

Appendix A

IERE's Sustainable Agriculture Program
Instructions to Farmers

Institute for Environmental Research and Education

Welcome to the IERE Agricultural Environmental Management Program. The program is based on international voluntary standards for environmental management (the ISO 14000 series) and has three components:

- a farm and facility based environmental management system,
- ecolabels which give a marketing edge to environmentally friendly products and
- a community environmental board, which links producers and processors to their communities.

Each element can stand on its own feet, but together they make a complete community based program.

ISO 14000 is a series of international consensus standards on environmental management. They lay out the way for any enterprise to manage its environmental impacts, and move towards sustainable practices. The primary document is the ISO 14001 standard, which bases environmental management on a continuous improvement approach, following the plan-do-check-act cycle. The idea is to make a plan, follow it, check to see how it is working, and based on that checking, act to make further improvements. This approach allows everyone to bite off the piece that fits in their mouths-- eventually eating the entire elephant.

Our program uses Life Cycle Assessment (LCA) as the measuring stick for measuring environmental performance. LCA is a science-based way to measure environmental performance of goods and services. It looks at all the environmental impacts of a product from cradle to grave, based on the useful function that that product provides. That means, for example, that the impacts of the resource production and manufacture, packaging, distribution and disposal are all included in the assessment. Doing a life cycle assessment takes time and requires a great deal of data, so our program steps people into the measuring system a bit at a time. Standards on doing an LCA are part of the ISO 14000 series.

The first step is to develop a farm-based environmental management system (EMS for short). This describes how you operate your farm, field by field, and how you are working to make it more environmentally friendly. We have some forms and examples that will take you through this process step by step. You do have to write down the elements of your EMS.

What drives your EMS is your annual farm plan. This is a description, field by field, of how you will manage your farm to reduce environmental impacts. But there are some other details that need to be taken care of first.

Farm Environmental Management System

Your farm EMS starts with your environmental policy statement policy statement. A policy statement tells the world what you think about the environment, and what you want to do about it. You should be able to paste your policy on the wall, and be able to look at it when you have forgotten why you are doing all this environmental stuff, and say, "Yes, that's why!" Everyone on your farm should know what the policy is-- you should discuss it around the dinner table to make sure that your spouse and kids know about it, and can see why you are doing what you are doing.

Even better, you should involve your family and any employees in writing the policy statement, so that it really reflects everyone's feelings and aspirations for environmentally friendly farming. The policy statement says what your aspirations are, and how you plan to get there. Somewhere in your policy statement, you need to commit to three things:

- Compliance with all environmental regulations
- Pollution prevention, and
- Continual improvement

Your policy statement can be as long or as short as you like, but it should be something you can live with and be happy with for many years.

Here is an example environmental policy statement:

> Jack's Farm tries to grow the best vegetables in the world, and being environmentally the best is part of being world's best. We want our farm to be completely sustainable. To do that we make an annual plan that everyone on the farm is responsible for knowing and following. Not only do we comply with all the regulations, but every year our plan makes us a little better environmentally. By polluting less, and by conserving our natural resources, we will make our vegetables a source of health and pleasure to our customers, and our farm will be a safe and healthy place for generations to come.

Here is another one

> The Blue Ribbon Dairy is an organic dairy, but we want to go beyond being organic to make milk products that fully protect our environment, going well beyond compliance. We want to decrease all the impacts of our products on and off farm, too. We follow the IERE program that uses life cycle assessment to measure these impacts. This helps us work with our suppliers to reduce pollution and conserve resources, getting a bit better all the time.

Your policy statement should be what makes sense to you.

Mechanics of the EMS

The environmental management system is what you are doing to protect the environment. The ISO 14000 standards tell you what you need to document to be sure that you have systems in place to accomplish your goals. The documentation should help you do what is necessary to protect the environment.

You will have to write down your EMS and farm plan, describing how you will get to your goals and objectives, and you will also have to keep records of your farm activities. There are also a few other things to document. These are important to protect the environment and to meet the requirements of the ISO standards. Your written EMS is a permanent document, although checking it out for accuracy form time to time is a good idea. Your farm plan changes every year, as you change what and how you are farming. The annual report is just what it says-- annual.

This may seem like a lot of paperwork, but in fact, we have streamlined it as much as possible and farmers that have worked with us on their EMSs uniformly say that the discipline of getting the data and records together has helped them to understand their farms better.

Compliance on a farm varies significantly depending on how you farm and where you are. You should know the environmental laws and regulations you need to follow on your farm. Some of these may be federal, some state, and some local regulations. The most common ones are

- FIFRA, the Federal Insecticide, Fungicide and Rodenticide act. If you apply pesticides, or have a contractor apply them, you may have to comply with the training and record-keeping requirements of this act.
- CWA, the Clean Water Act. In some states, there are activities related to the management of manure and runoff from the land that are regulated under this act.
- CAA, the Clean Air Act controls (among many others) the use of Freon. If you have a cooling system that uses Freon, you or your contractor need to have training and keep records about its use.
- Noxious weeds. Many counties regulate the control of noxious weeds. Usually they require that you control the weeds on your land. Sometimes they tell you how to do that control.

There may be other regulations you need to know about-- find out by calling your local state environmental regulators and your cooperative extension agents. Keep a copy of any regulations that you need to follow, and keep any record they require.

Keeping Records should not be a complicated thing. You may keep your records in a pocket calendar that you carry with you as you go about your work on the farm. This is what we recommend if you have a small farm. Or you may be relying on the contractors that do things like applying your pesticides. You may be putting your records into a book in the milking barn. Regardless of how you keep your records on a day-to-day basis, remember from time to time to put that information into a file of what you did for that field. This has to happen at least once a year, and on a small farm this may well be enough. If you are managing a larger property, though, you may find it easier to organize your data more frequently: quarterly or even monthly. Your EMS should state how you are keeping records, and making sure they are being updated properly. Some of your records may be required by law, especially if you apply pesticides yourself.

Monitoring is all the day to day observations you make to keep track of the farm and tis environmental status. That means checking soil moisture, scouting for pests, tracking milk production and so forth. If you run a feedlot and have monitoring wells, monitoring includes the measurements you make in those wells. Monitoring data tells you when you have to make corrective actions.

Corrective Actions are mid-course adjustments during the year. This means you are thinking ahead to make sure that you meet your goals and objectives. For example, if you planned to reduce pesticide use by 50%, and you find you are close to the 25% before spring planting is over, you may want to change how you are doing things, to give yourself some room to use pesticides later during the year. Or if you planned to put in a fence to keep the cattle out of the wetlands, and it is November and you haven't ordered the fencing material yet, you can still get that fence ordered and installed before the end of the year. But even without making summary records, thinking about your environmental goals as you work around the farm, you will be able to see where you are off track and make corrective actions. Write them down when you make them.

Your EMS must state how you are going to perform monitoring and corrective actions. That means that you need to write down how you are checking things out. If you are doing a manual check of the soil moisture (seeing if it clumps) then you write that down. If you are using a soil moisture meter, write that down. The point is not to have the fanciest monitoring system, but to make sure that you have a way to monitor everything that matters.

Likewise, write down your corrective action decision points. That means that you should know the insect density that becomes a financial burden, so you know when to apply insecticides (if ever). Every state has an IPM specialist who can tell you what these decision points are.

Make a table of your monitoring methods and corrective action points.

Operational controls are the things you do to make sure you will maintain good environmental quality, and meet your improvement goals. Examples of operational controls are the way you manage your manure, and the use of monitoring for pesticide, fertilizer and water application. Another example of operational controls is use of low till or no-till methods.

Preparing for emergencies is an important part of environmental planning. What would happen to the environment if you suffered a tornado or earthquake or flood? Do you have manure lagoons that could overflow? Are you storing pesticides that could be distributed all over the county? Spend some time to think about what could happen to the farm in the event of a natural disaster, and what you should do if they happen. This should lead you to finding ways to make emergencies NOT happen. You need to write down your emergency plan.

Internal communications. If you have any employees (even if they are family members), you must keep them informed about your environmental plans. They need to know about your policy statement, and they need to know what they must do to help you meet your goals and objectives.

External Communications: The IERE plan requires that you write an annual report about your farm's environmental program. We post that report on our website. Every annual report has the following elements:

1. A business description:
2. Your Environmental policy statement
3. Your environmental aspects
4. Your goals and objectives
5. Information about environmental compliance
6. Your plan for the year, and how you did last year versus that plan
7. Contact information

Auditing. This is one of the "checking" parts of the EMS. At least once a year, you need to go over your environmental performance: did you meet the goals you set yourself? Look at your corrective actions, to see if there is some pattern indicating that a particular system needs changing.

Ideally, you should have an outside person go over your records with you so that a fresh pair of eyes can see your opportunities for improvement. IERE will do a paperwork review of your farm. If funds are made available we can do an on-site review. This may be from one of our offices (in Seattle and in Davenport, IA), or it may be from IERE trained community environmental council members.

.

Your Farm Plan

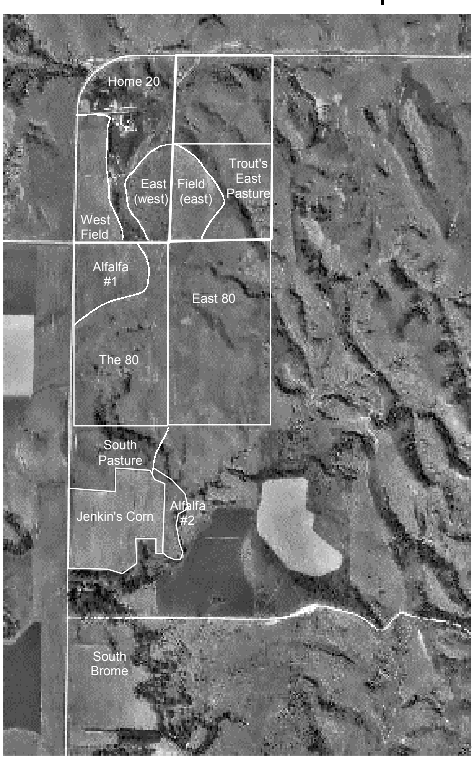
The farm plan has five steps:
1. Gathering data on farm activities
2. Evaluation of Environmental Aspects and Impacts
3. Setting goals and objectives
4. Implementing the goals
5. Communication

At the end of the year, you will also have to evaluate your progress versus your goals and objectives.

Data Gathering

You manage your farm one field at a time. So you need to gather data about the activities of your farm one field at a time. The first step in developing your plan is to identify each field you have, where it is and some basic characteristics such as how large it is and whether it is irrigated. To do this you need a map of your farm, and mark each field's location.

Your cooperative extension agent can get you a map, or, if you are linked to the internet, you can get a satellite photo of your farm. Once you have a map, you need to mark off the fields. The map below is an example where this has been done.



Be careful in identifying your fields. If you sometimes plant half of a field one way and the other half another way, you really have two fields, and should give them different names. Some people number their fields, and that is OK, too. The key is to know what land you are talking about, and have a unique identifier for every parcel that is managed as a unit.

The next step is to make a table of your fields, showing the activities for each field: what you grew on that field last year, and all the cultural practices you used. The cultural practices include how you tilled the soil (when and how and how often) how you fertilized the soil (when and with what and how much), how you used pesticides, if any (when what and how much), what you planted (what, when and how much), and how much you irrigated each field. Note how much fuel or electricity you used to manage each field.

Finally, figure out your yields from each field. If you are growing grain, this is easy. You should have records of bushels yield or tons sold. If you are raising animals it is a bit more complicated. You should note animal days of grazing as well as the marketable yield, such as hundredweight of milk produced or pounds of animal sold less pounds of animal bought. Finally, make one more table where you add up all the numbers to get an overall farm picture for the year: the inputs, and the production. In this last table you need to put in any on-farm processing, and any transportation of your crop.

The last set of data needed id the soil quality data. For each field. You should measure the following properties: Organic carbon, topsoil depth, nitrate + nitrite, TKN, Phosphate, and potassium. This information will help you decide whether and how to fertilize your fields, so the best time to measure them is before planting. It will also provide us the information we need to calculate the impacts of your farming practices.

Evaluating Aspects and Impacts

Now you have a record of what you did last year, and can start to understand what are the environmental aspects for your farm. Here is where you start thinking about your farm from an environmental perspective. You want to know and understand the environmental aspects of your farm that may cause environmental impacts, and know how they are linked to your farm activities, products or services.

Below is a list of the environmental aspects and potential impacts of farm activities.

Activity	Environmental Aspect	Potential Impact
Tillage	Burning fossil fuels Releasing carbon fixed in soil	Climate change; acidification; eutrophication; soil erosion; destruction of habitat; fossil fuel depletion
Planting	Burning Fossil Fuels	Climate change; acidification; eutrophication; fossil fuel depletion
Fertilizing	Use of nitrogen, phosphorus, sulfate and potassium; using fossil fuels	Climate change; acidification; eutrophication; human health effects from groundwater; salinization of soils; destruction of soil microorganisms; fossil fuel depletion
Pesticide Application	Pesticide use and release; fossil fuel burning	Climate change; acidification; eutrophication; human and ecosystem toxicity through pollution of air, water, groundwater and crops; fossil fuel depletion
Irrigation	Use of water; burning fossil fuels or using electricity	Climate change; acidification; eutrophication; water resource depletion; salinization of soils; fossil fuel depletion
Cultivation	Burning fossil fuels Releasing carbon fixed in soils	Climate change; acidification; eutrophication; destruction of habitat; fossil fuel depletion
Harvesting	Burning fossil fuels; removal of fixed carbon	Climate change; acidification; eutrophication; fossil fuel depletion
Processing	Burning fossil fuels or using electricity; possible use of water or freons	Climate change; acidification; eutrophication; water resource depletion; stratospheric ozone depletion
Transport	Burning fossil fuels	Climate change; acidification; eutrophication; fossil fuel depletion

You already have a list of your activities, and numbers on your environmental aspects: how much fuel you used, what pesticides you used and how much, and similar things. You need to take that list and decide which ones are important, and which ones are not.

Think about your environmental aspects two different ways to make this decision. First, is the ***impact*** important? The answer to this question depends on your values, and what you know about your local environment. For example, suppose you are looking at the aspect of water use, and you live in Arizona. You KNOW that water depletion (the impact of water use) is important. Fresh water is a very limited resource there. If you live in New England, water resources are abundant, and water resource depletion would be rated low. Rate each impact as high, medium or low. Global warming and stratospheric ozone depletion should both be rated high, because they are world-scale and long-term problems.

Second, ask whether the amount or size of the **aspect** is large. Are you using pesticides only on invasive species, and only using hand application? Then rate that aspect low. Are you only using water to water your stock (not irrigate the crop)? Then the water usage and this environmental aspect are low.

Once you have gone through the aspect and impact rating (high, medium or low), then look to where you have high-high ratings as the place where you might want to make some improvements. If you don't have any high-high ratings, then look at the medium-high or high-medium ratings as the opportunities to improve. Every aspect that you rate as high-high must have a plan for it. That means that you must be looking at ways to reduce its impacts. Sometimes there is no obvious "fix." You should still have a plan to get more information on the problem, or to keep track to new technologies or ideas.

When you have been managing your farm's environment for a year, we will be doing a life cycle assessment of your farm products. This will look at the environmental impacts of the products, evaluating not only on-farm activities, but also the things that happen off-farm (like transport and packaging). A life cycle assessment is the basis of the ecolabel that IERE provides. Once a life cycle assessment has been done, you will be using the impact indicators, rather than the environmental aspects to manage and measure your environmental performance.

Setting Goals and Objectives:

This is the part of the plan where you decide what you want to take on to improve the environmental performance of your farm. These are your goals and objectives for the year Using your ratings, pick out the things that you can do to improve your environmental performance in the next year.

You probably noticed that the environmental aspects can be described with relatively few items: burning fossil fuels; disturbing the soils to reduce fixed carbon; using fertilizers and pesticides and using water. You can make significant environmental improvements on the farm by employing just a few practices:

- Reducing tillage (low-till or no-till farming)
- Practice integrated pest management (IPM)
- Only irrigate and fertilize when you have to.

There are some more advanced techniques you can use, too, such as:

- Protecting zones near waterways
- Using intensive grazing to grow animals
- Planting native, mixed species crops

For example, you might decide to practice no-till farming in one field. Or you might want to overplant one pasture with native species. Or you might choose to hire an agricultural consultant to do your scouting for IPM. Pick out the ones that you can afford, and that you have the time to do. You want your plan to be successful! Even if you only pick out one thing to do, you will be making the environment better.

Regardless of your goals for the year, you need to write them down, and you need to gather data on what you did to meet that goal. Ultimately, you will be reporting how you did versus those goals, so it is a good idea to choose goals that are feasible with the resources you have at hand.

Reporting Progress: The Annual Report

Once a year, you will be preparing an annual environmental report, and we will post that report on our web-site. The goal of this report is to tell the world that you had a plan, and how you performed versus that plan. The elements of the annual report are:

- A description of your business: what you grow, how big you are, who owns/operates the land and so forth. This section is where you have an opportunity to put a numan face on your farm. We strongly recommend that you take pictures to be included in the section and others.
- Your environmental policy statement
- The list of your environmental aspects, and your goals for the year related to them. After the first year, this list will be of Life Cycle Impact Categories, and your goals will be numerical (e.g., setting a reduction of 10% Global Warming Potential).
- Your compliance issues (if any). Here is where you list the environmental regulations that apply to your farm (there may not be any), and any non-compliances you may have. IERE will not post your report if you have substantive non-compliance. That means that if you have a non-compliance that has no discernable environmental impact (e.g. some documents are missing), you are OK, but not if you have a significant spill, or release of a regulated substance (even an unpermitted release from a lagoon). You will need to go for a year with a clean slate before you can get the benefits of the program.
- Your goals and objectives for the last year, and how you did versus them.
- Your contact information (how can people get to you if they have any questions).

Example annual reports can be found on our website www.iere.org/sustain/.

Ecolabels

Ecolabels are the economic driver of IERE's program. Ecolabels for foods have been found to provide significant price advantage at retail, sometime as much as 200%, but 40% is more common. IERE's program is based on the ISO 14000 standards for ecolabels, and they are a Type III ecolabel. That means that they are based on a life cycle assessment of the product. We look at the environmental impacts of agricultural products in what we call a "cradle to plate" approach. On farm, that means that we look at the inputs and outputs of every field, and model all the impacts for which there are reliable models. Off farm, we model the impacts of the production of fertilizers and pesticides and fuels, the impacts of electricity production, and all transportation costs, as well as impacts from processing, packaging and refrigeration.

It is a lot of data collection, and we don't expect to have everyone have all the information for their ecolabels right away. What we do expect, is that the farmer provide all the relevant on-farm data within a year of joining our program. We will be using industry averages to estimate the off-farm environmental impacts. In subsequent years, we expect that some of the off-farm data will begin to be collected, so that we can model the specific impacts of the farm product.

The Impact categories we will be modeling include:

Impact Category	**Units of Measure**
Climate Change	CO_2 equivalents
Stratospheric Ozone Depletion	Freon equivalents
Acidification	Hydrogen ion equivalents
Eutrophication	Phosphorus equivalents
Photochemical smog	Ozone equivalents
Airborne toxicity	Toxic units
Waterborne toxicity	Toxic units
Water Resource Depletion	Equivalent tons of water
Mineral Resource Depletion	Equivalent tons of resource
Land use/Biodiversity	Square meters; proportions
Soil Depletion	Tons of carbon
Fossil Fuel Depletion	Tons of Oil Equivalent

In addition, we will be reporting, but not modeling, the following information:

- Use of gene modified organisms
- Use of sub-clinical antibiotics
- Use of growth hormones

Regardless of the indicator, we will be reporting the result in comparison with the US average for that environmental category. This will permit interested parties and especially consumers to put the environmental efforts of the farm into perspective. No ecolabel will be provided for products that are not better than average on all environmental indicators.

Land Use and biodiversity is a special issue for ecolabels, in that there is no consensus about which indicators are best to measure this impact. Nevertheless, there is clear consensus that land use changes are the most important source of environmental degradation that derives from agricultural practices. We are working with a coalition of experts and interested parties on this issue, and until we reach consensus on the best indicators (a process which is expected to take years), we will be using the following indicators:

Proposed Measures
Acreage of habitat that is physically protected (i.e.; through fencing or other methods); habitat to be identified as including • 100 feet each side of rivers; • maps with location of T&E species
Acreage of habitat set aside (not farmed) that is identified as "high priority" in TNC vegetative maps
Total linear space of aquatic habitat (i.e. river, lakeshore, etc) protected via physical means vs. total area managed
For physically protected areas, density of non-native vegetation (area percent)
Miles of road per square mile
Acreage in native species dominated areas/total area managed
Acreage newly returned (in last 12 months) to native habitat
Number of Best Management Practices (i.e. operational control related to biodiversity) adopted
Size of native-managed acres vs. total acres managed Size of native-managed acres vs. average field size
On managed acres, percent of native-managed land units that has at least one adjacency to other native-managed land

Appendix B

Life Cycle Assessment of Agricultural Products
IERE's Program

Life Cycle Assessment of Agricultural Products

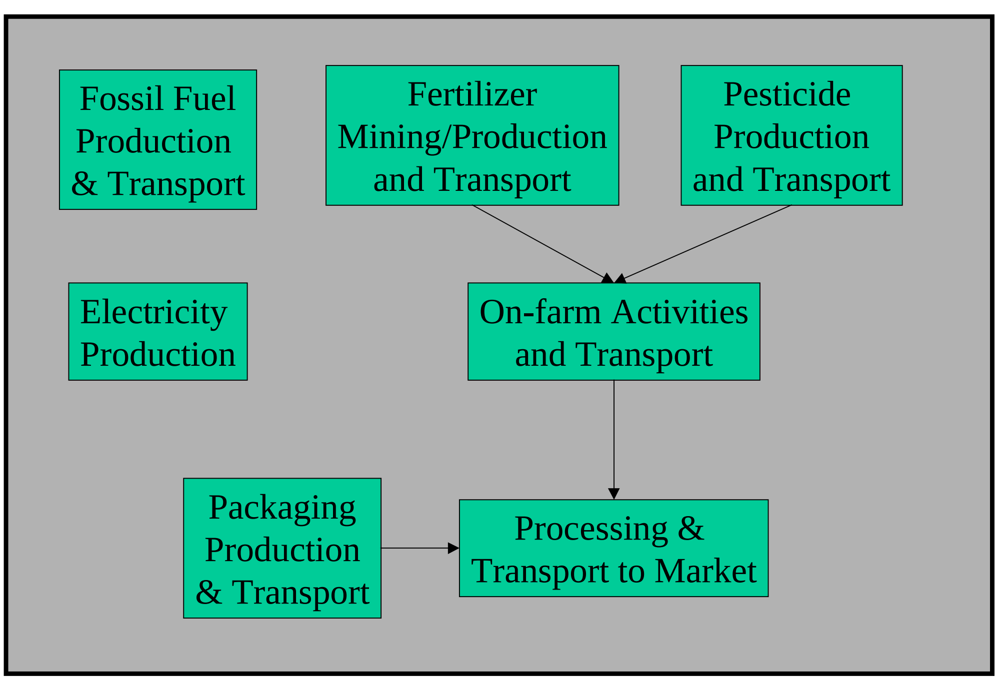
IERE (the Institute for Environmental Research and Education) has been working with farmers to improve their environmental performance. We are measuring that performance with a technique called Life Cycle Assessment or LCA. An LCA evaluates the environmental impacts of products from cradle to grave in a holistic fashion. All applicable environmental issues should be evaluated, as long as the mechanism of impact is understood well enough to allow a science-based assessment.

We are requesting the input of all interested parties to validate the scope of our LCA. In particular, we wish to have input on two things: the list of environmental impact categories that we plan to evaluate, and the boundaries of what we plan to evaluate. In particular, we are asking for input as to whether there are any important issues related to the environmental impact of agricultural products that are not being addressed here, particularly if one has information on how such impacts might be modeled and evaluated.

Please send any comments to rita@iere.org.

The figure below shows the boundaries of what we are considering in the LCA. We call it a "cradle to plate" analysis, because we ignore any impacts from the point the product leaves the retail market. We do this because the environmental impacts of this part of the life cycle are highly dependent on how the consumer chooses to prepare the food, and we have found little information about this aspect of food impacts. Also, we believe that there will be no significant differences between how consumers prepare environmentally friendly food products versus conventionally raised food products. A

Figure 1 LCA System Boundaries



similar argument can be made for non-food farm products. If anyone has information contradicting this assumption, we would be very interested in hearing about it.

The green boxes in the figure represent unit processes. Arrows connect them where mass and energy flows between the unit processes occur. Note that electrical generation and fossil fuel production and transport are used for all the other unit processes. We have left out the arrows to simplify the figure.

Information on fossil fuel and energy production is taken from the LCAdvantage database produced by Battelle. This database is the best available for the US energy system.

It is our intent to use as much site-specific information as possible in modeling the environmental impacts of the farm system. At a minimum, that means that all farm inputs and outputs are specific to particular farms (in fact, to particular fields). We are requesting that all farms work on getting more site-specific information from their vendors and customers, and in subsequent iterations of the LCA, this site-specific information will be used. For the first round of LCA's, we will be evaluating the off-farm unit processes using US average data collected from government statistics, from published resources, from commercial databases and from industry sources.

We believe that this approach is legitimate because, with the exception of electrical generation, the majority of the environmental impacts of agricultural products are expected to occur on-farm. For example, if we evaluate the impacts of the production of pesticides, we can expect some small releases of the pesticides to the environment during production and handling and transport. However, much more than 90% of the pesticide release will occur on-farm. We request that anyone having information that either supports or contradicts this assumption please contact us at rita@iere.org.

We are attempting to perform a comprehensive review of the impacts of agricultural products. We have attempted to include all environmental impacts that can be modeled, but we are also including information about some issues that no clear models are available for. An example is the use of gene-modified organisms. Although the environmental risks associated with GMO's are not known, we are requesting that farmers provide this information, because international packaging standards require that this be disclosed.

The Impact categories we are evaluating are shown below. You can click on them to get more information about them.

IERE List of Impact Categories for Agricultural Product LCAs

Climate Change
Stratospheric Ozone Depletion
Eutrophication
Photochemical Smog Formation
Acidification
Airborne Toxicity
Waterborne Toxicity
Water Resource Depletion
Mineral Resource Depletion
Land use/biodiversity Conservation
Soil Conservation
Hormone Use
Antibiotic Use
Gene Modified Organism Use

IERE's Threshold Approach to Impact Assessment

Our modeling approach is based on the concept that natural systems have a certain capacity to absorb environmental insults. Until that assimilative capacity is used up, we assume that no environmental damage exists.

In the case of emissions impacts, such as acidification impacts, we model the deposition of acidifying substances, and use available maps to determine what percent of that deposition occurs in sensitive environments. If none of the deposition occurs in such a location, then we say that there is no impact. Most of the continental US is relatively insensitive to acid deposition, either because it has alkaline soils or underlying limestone or a source of neutralizing substances is transported in the air from a source upwind. In the case of pesticides and other toxic materials, We assume that all toxic materials leaving the field can cause impacts downstream or downwind. This assumption is based on the observation that pesticides undergo may cycles of evaporation and precipitation, and tend to concentrate in colder climates. Thus any pesticides leaving the property (but not those staying on-site) we consider to have an impact and calculate that impact with a toxicological model.

In the case of resource impacts, we modify the impact by the size of the resource base and whether it is renewed. Renewal includes recycling of minerals and natural recharge of aquifers and the like. If a particular aquifer recharge is greater than its use, then we say the impact is below the assimilative capacity of the environment.

The use of thresholds in evaluating environmental impacts in a relatively common practice in LCA's however, it does represent a value choice, and other options exist to evaluating impacts. We seek comments from interested parties as to whether this approach is reasonable and acceptable.

The Greenhouse Effect and Global Climate Change

Light and heat are continually radiating from the sun to the earth and from the earth to space. The balance of radiation in and out controls our climate and weather. Greenhouse gases change that balance.

When the sun shines on the earth, the atmosphere absorbs some of the radiation, but some sunlight reaches the earth's surface. When it reaches the surface of the earth, some of it is reflected back into space. Different parts of the earth reflect more or less sunlight. The sunlight on snow or ice mostly bounces right back out. The sunlight on dark soils and forests is mostly absorbed. Some of the light that is absorbed gets re-radiated as heat.

Greenhouse gases are like a blanket around the earth. They absorb the heat from the earth, and re-radiate it: about half gets sent out to space, and the other half goes right back to the earth's surface. The most important greenhouse gases are water vapor and carbon dioxide (CO_2), but there are many others, some artificial and some naturally occurring. Overall, the greenhouse effect is a good thing. It is a cold universe out there (on average, only a few degrees above absolute zero). Without greenhouse gases, the earth would be a frozen lifeless ball.

The problem with greenhouse gases is that over the last few hundred years (since the industrial revolution), the concentration of greenhouse gases in the atmosphere, especially CO_2, have gone up a lot. That is because we are burning lots of fossil fuel to make power, and to run our cars and heat our homes and to operate industrial equipment. When you burn fossil fuel, you make CO_2, and the CO_2 then makes a thicker blanket around the earth. It's as if you were wearing a nice, light jacket in the Spring, and then put over that jacket a heavy parka. You would start to get too hot.

It doesn't take a lot of change in the earth's temperature to make a difference in our weather. That is because differences in temperature in the atmosphere and in the ocean control the wind and ocean currents. Sometimes it only takes a few degrees to alter circulation patterns. Exactly how the ocean and atmosphere work together with the radiation balance of the earth is not well understood. But scientists are studying this and as a result, we are getting better at predicting weather patterns on a longer scale.

One weather pattern that is getting to be much better understood is the El Niño/Southern Oscillation effect. The Pacific Ocean covers almost half of the earth's surface, and the water sloshes back and forth across the basin as if it were a big bathtub. When it sloshes in one direction, we get the El Niño. When it sloshes the other way, we get the La Nina. In between we have "normal" weather patterns. It is changes in the temperature of the water near the equator that control the sloshing, and scientists believe that global warming is making the back-and-forth pattern more intense.

There are certain to be other ocean/air linkages that control our weather-- but we just don't understand them very well.

There are other greenhouse gases besides CO_2. One important one is methane (which comes from natural gas, cows and other animals, and rice paddies. Another is nitrous oxide (which comes as a by-product of burning). Many of the refrigerant chemicals are very good greenhouse gases, too. How much warming comes from a particular gas depends on three things: 1) how well the gas absorbs heat radiation 2) how much there is in the atmosphere, and 3) how long the gas survives in the atmosphere. CO_2 and nitrous oxide survive about the same length of time in the atmosphere (over a hundred years!), but nitrous oxide is about 300 times better at absorbing heat. It is a good thing that there is so little nitrous oxide in the atmosphere!

How Climate Change Relates to Agricultural Products

Much of the greenhouse gases that derive from agricultural products comes from the use of fossil fuels to provide power and transport, not only on-farm but also in food processing and storage. But there are also significant on-farm sources of greenhouse gases. Ruminants such as cows, goats and sheep produce large quantities of methane a byproduct of their digestion. Methane and nitrous oxide also come from rice fields and from manure management practices.

At the same time, it is possible to take CO_2 out of the atmosphere with appropriate farm practices. The carbon ends up in the soil, and we call this sequestered carbon. Our evaluation of climate change on the farm includes the carbon sequestered by farm practices (if any). You can learn more about how we calculate this impact by clicking here.

Stratospheric Ozone Depletion

In the upper layers of the atmosphere (the stratosphere), the radiation from the sun reacts with oxygen and forms ozone. This three-atom form of oxygen absorbs ultraviolet radiation (UV) very well, and the thin layer of ozone protects all life on earth from the harmful effects of UV radiation. Too much UV radiation causes skin cancer and cataracts, and also is very detrimental to plants.

There are several man-made compounds (freons and other halogenated compounds) that act to destroy ozone in the atmosphere. These compounds are usually used in refrigeration and in fire suppression, although they also have some other applications as solvents. Over the years, the release of these compounds through leaks in refrigeration systems and the like has led to the creation of ozone holes at the north and south poles.

Ozone holes form at the poles because in the winter, there tends to be circumpolar winds that keep the same piece of air circulating at the pole. Because it is dark during the entire winter, there is no sunlight to create new ozone while the old ozone is being destroyed by halogenated compounds. In the summer, the circumpolar winds break up, and there is mixing of the ozone-free air to lower latitudes. This causes ground-level UV to be quite high in places like South Africa and southern Australia, and northern Canada.

Different halogenated compounds have different capacities to destroy ozone, as well as different residence time in the atmosphere. Some halogenated compounds have an atmospheric lifetime of over a thousand years. Just like greenhouse gases, a scale has been developed that compares the strength of different ozone depleters to a standard, in this case to CFC-11.

The amount of halogenated substances in the stratosphere is going down, because international agreements have phased out their manufacture. Nevertheless, the ozone holes are still getting bigger and bigger. It is not clear why this is happening. Some scientists think it may be related to climate change modifying the radiation balance in the atmosphere.

Ozone Depletion and Agriculture

Many agricultural products are refrigerated to maintain their freshness. We evaluate stratospheric ozone depletion through records on the release of halogenated compounds from refrigeration systems. Fire suppression systems for agricultural systems on farm and in processing facilities do not use ozone depleting substances.

Eutrophication

How much plant matter (algae) there is in natural waters depends on whether the water contains enough of the nutrients needed to support life. When too much nutrient is in the water we get algal blooms (pond scums in freshwater and red tides in seawater). The process of over-fertilization and the subsequent algal blooms is called Eutrophication.

Algal blooms are more than just more plants in the water. Some algal blooms are toxic. For example, Pfisteria on the East Coast, and the red tide organisms that are common in many inshore areas. Red tides can produce toxic effects in fish as well as in people. If enough algal bloom occurs, it will cause loss of oxygen from the water as the algal bloom dies and sinks to the bottom. The loss of oxygen or anoxia, causes all organisms in the water column to die. This happens in large parts of the New York bight and in the Gulf of Mexico every year.

Eutrophication occurs in aquatic systems when the limiting nutrient in the water is supplied, thus causing algal blooms. In fresh water, it is generally phosphate that is the limiting nutrient, while in salt waters it is generally nitrogen that is limiting. In general, addition of nitrogen alone to fresh waters will not cause algal growth, and addition of phosphate alone to salt waters will not cause significant effects. In brackish waters, either nutrient can cause algal growth, depending on the local conditions at the time of the emissions.

There are some indications that similar sorts of effects occur in terrestrial systems as well.

Eutrophication and Agricultural Systems

Farms are a primary source of eutrophication in the US. Excessive use of fertilizers on farms, and poor manure management mean that nutrients are released from the farm into the air and the waterways. How much is released off-farm depends on the management practices used on -farm. For example, when animals are grazed in well-managed pastures, essentially all the nutrients in the animal waste are retained in the soils. However, when animals are raised in confinement, using manure lagoons, as much as 90 percent of the nitrogen is lost to the atmosphere.

This nitrogen drifts downwind and eventually reaches marine water, causing problems there.

Photochemical Smog

Smog results from the action of sunlight on volatile organic compounds in the presence of oxides of nitrogen. The reactions are complex, but the outcome is the creation of ozone and other noxious chemicals. Ozone is toxic to all life. It causes mutations that can lead to cancer and to birth defects and premature aging.

Most agricultural settings have no deficiency of organic compounds in the air: plants give them off as they grow. Therefore, the limiting factors for the production of smog in agricultural areas are the presence of sunlight and nitrogen oxides. Nitrogen oxides come primarily from the burning of fossil fuels, and the use of these fuels is the basis of our estimates of photochemical smog on the farm.

In urban settings, the limiting factor is typically the presence of volatile organic compounds. These come form the use of solvents, and from spills of fuel oil and gasoline, as well as incomplete combustion of fossil fuels.

Acidification

Acidification is the process by which acid gases in air deposit on sensitive land downwind. This deposition can be as dry deposits, or it can be as rain, snow fog or other precipitation. Acidification alters soil chemistry, leading to toxic effects on plants. It also can cause lake and rivers to become acidified, killing many of the organisms that live there.

How bad acidification is depends on the soil types where the deposition occurs. Some soils have a high neutralization capacity, and relatively little occurs as a result of acid deposition. Some soils have very little soil neutralization capacity, and here we can see effects such as the die off of trees and other plants, and the loss of biodiversity in aquatic systems. Acidification also has a bad effect on urban environments, because the buildings and other structures are slowly being dissolved by the acid deposition.

Acid gases are primarily derived from combustion processes in transportation and in heating and electricity generation. On the farm, the issue is the location of the farm and whether the soils downwind have the capacity to neutralize these acid gases. Farms can also have a significant source of ammonia, if manure is not properly managed. The ammonia can lead to acidification of soils as well as other problems downwind.

Airborne Toxicity and Waterborne Toxicity

These impacts are exactly what they sound like. They are based on the release of toxic substances into the air or the water. We do not make separate categories for human toxicity and ecological toxicity because the vast majority of toxicity data is derived from experiments with rodents. Therefore to call toxicity estimates based rodents "human toxicity" indicators appears to us to be misleading.

Although every toxic substance has a different mechanism of action, and different responses in different species, there is no consensus in the scientific literature as to how to combine these different effects. Our approach is to calculate the concentrations of toxic substances in water and air at the property or field boundaries and report both individual substances exceeding the no-effects level, and a combined score of toxic units which is based on multiples of the no-effects level.

Mineral and Water Resource Depletion

In the context of sustainability, we must ask the question: are we using up resources that will make future generations unable to develop or maintain their quality of life equivalent to our own? The issue here is whether the resources used in producing agricultural products can be replaced or renewed.

Fossil fuel burning is a classic example of a resource that cannot be replaced. On the other hand, water used for irrigation and other uses can be replaced, and the issue is whether it is being replaced, or recharged for the particular water source (an aquifer or river system).

In the American Southwest and in places around the globe such as the Middle East and sub-Saharan Africa, the water resources are being depleted at an alarming rate. Some analysts predict water wars in this century.

We evaluate resource depletion based on a model that incorporates use and recharge, and permits the direct comparison of different resources. We calculate indicators for water resources, fossil fuels, and mineral resources.

Soil Conservation

To a great extent, American farmers have been mining the soil for the last 100 years. As the soils erode away, so does our food security and that of future generations. Many farmers are combating soil losses through no-till farming, conservation tillage and other techniques. One thing that all these methods have in common is that they increase the amount of soil organic carbon, and thus we evaluate soil conservation using the concentration of carbon in the soils, and its change over time.

Soils with high organic carbon are more fertile. Less likely to erode, have richer soil ecology, require less irrigation, and even act as a carbon sink from the atmosphere, thus decreasing global warming.

Land Use/Biodiversity

It is an unavoidable effect of agriculture that we replace natural ecosystems with crops. Without question, agricultural activity has led to the loss of more species and habitats than any other human activity. We need to farm to feed our populations, but there are ways to help maintain species diversity and healthy ecosystems in agricultural settings.

For example, farmers can protect areas near streams, or they can raise cattle and other animals in grazing systems based on native prairie ecosystems.

We are currently working with the Defenders of Wildlife to develop indicators of land use that can be used for land use in all setting, rural and urban.

Hormone Use, Antibiotic Use and Gene Modified Organisms

At the moment, debate is raging as to whether the use of hormones or of gene modified organisms causes any environmental or human health effects. The logic is that the hormones in animals and animals products enter the human food chain and eventually causes hormonal effects in consumers.

Gene modified organisms are even less clear-- there is some data that shows that the pollen form some strain of gene-modified corn kill monarch butterflies, and there certainly is some logic that the genes for pesticides expressed in food crops may result in pesticides in the food supply. On the other hand, some gene modified crops have been modified to have higher levels of vitamins or better balanced proteins. No one appears to be arguing that his is a bad thing.

Our approach is simply to report the use of hormones and gene modified organisms and let the consumer decide whether to accept the product based on this information.

Antibiotic use, on the other hand is known to cause hazards to human health. The problem comes when animals are fed antibiotics on a daily basis-- such additives increase growth rates, so this is a common practice. The microorganisms in the guts of these animals develop resistance to those antibiotics. These microorganisms represent a very large pool of antibiotic resistance.

The problem is that bacteria exchange antibiotic resistance across species lines, so the antibiotic resistance can and does get shared with human pathogens. That means that we now have strains of disease causing bacteria that are resistant to all known antibiotics, and deaths have occurred as a result.

We evaluate antibiotic use by calculating the amount of all human antibiotics fed to animals, and adding up the moles fed. This calculation accounts for the different sizes of molecules of antibiotics.

References

[i] Campbell, J. 1992. Lice control on Cattle. University of Nebraska Nebguide. G92-1112-A

Campbell, J. 1993. Dairy Cattle Insect Management. University of Nebraska Nebguide G93-1141-A

Campbell, J. 1993. Stable Fly Control on Cattle. University of Nebraska Nebguide. G93-1152-A

Campbell, J. 1993. Sanitation for Fly and Disease Management at confined livestock facilities University of Nebraska Nebguide. G93-1175-A.

Campbell, J. 1993. Horn Fly Control on Cattle. University of Nebraska Nebguide. G93-1180-A

Campbell, J. 1994. Face Fly Control on Cattle. University of Nebraska Nebguide. G94-1204-A

Campbell, J. 1990. A Guide for the Control of Flies in Nebraska Feedlots and Dairies. University of Nebraska Nebguide. G77-355

Campbell, J. 1989. Cattle Grub Control in Nebraska. University of Nebraska Nebguide. G78-409

Koehler, P. G and J. F. Butler. 1999. Livestock Pests. http://edis.ifas.ufl.edu/scripts/htmlgen.exe?DOCUMENT_IG048

Lysyk, T. 1996. Livestock IPM. Agriculture and Agri-Food Canada, Lethbridge, Alberta, CANADA Contribution No. 3879694

Townsend, Lee. 1994. Biological Control of Flies. University fo Kentucky Cooperative Extension Service. http://www.uky.edu/Agriculture/Entomology/entfacts/livestc/ef502.htm.

Peters, L.L., B. Doupnik, and R. Pierce. 1988.Pest Management of Farm-Stored Grain. University of Nebraska Nebguide. EC 88-1534.

Wright, R.J. and J.F. Witkowski. 1998. Corn Insects - Quick Reference. University of Nebraska Cooperative Extension EC98-1562-B

Hein, G. L. J. B. Campbell, S. D. Danielson, J. A. Kalisch. 1993. Management of the Army Cutworm and Pale Western Cutworm. University of Nebraska Nebguide. G93-1145-A.

[ii] Nebraska Cattlemen. 2000. Beef State Facts. www.nebraskacattlemen.org.

[iii] United States Department of Agriculture National Agricultural Statistics Service Ag Ch 1 (00) Agricultural Chemical Usage 1999 Cattle and Cattle Facilities April 2000

[iv] Wenzel and Hauschild, 1998. Environmental Assessment of Products, Volume 2, Scientific background.(Thompson Science. London) 565pp.

[v] Halley, B.A., T.A. Jacob, AYH Lu, M. Sharp. 1989. The environmental impact of the use of Ivermectin: Environmetal effects and fate: Chemosphere 18:7-8, 1543-1563.

Nessel, R.J., D.H. Wallace,T.A. Wehner, W.E. Tait and L. Gomez. 1989. Environmental fate of Ivermectin in a cattle feedlot. Chemosphere. 18:1531-1541.

Wratten, S.D. and A.B. Forbes. 1995.Environmental assessment of veterinary products with particular reference to the avermectrins. Pesticide Outlook April 1995), pp 20-24.

[vi] Van der Werf, H. M.G. and C. Zimmer. 1997. An indicator of pesticide environmental impact based on a fuzzy expert system. http://pmac.net/benbfuz1.htm

Teske, M.E. S.L. Bird, D.E. Esterly, S.L. Ray, and S.G. Perry. 2000. A User's Guide for AgDRIFT 2.0: A Tiered Approach for the Assessment of Spray Drift of Pesticides. CDI Report No.99-01

.vi Jones, R.L. and M. H. Russell, Editors 2000FIFRA Environmental Model Validation Task Force Final Report (October 3, 2000) Prepared on Behalf of The FIFRA Environmental Model Validation Task Force,

[vii] Civil/Environmental Modle Library (CEML). 2000. PRZM3.
http://www.cee.odu.edu/cee/model/przm3.html.

General Overview of GLEAMS. 2000.
http://www.cpes.peachnet.edu/sewrl/Gleams/gleams_y2k_update.htm

[viii] Woodrow, J. E, J.N. Seiber and L. Baker. 1997. Correlation Techniques for estimating pesticide volatilization flux and downwind concnetrations. Environ. Sci. Technol. 31:523-529.

[ix] Scholtz, M. Trevor Bill J. Van Heyst, and Alvaro Ivanoff. 1999. Documentation for the Gridded Hourly Atrazine Emissions Data Set for the Lake Michigan Mass Balance Study - A Final Contract Report, , EPA 600/R-99/067.
[x] Schottler, S.P. and S. Eisenreich. 1997. Mass balance Model to Quantify Atrazine Sources, Transformation Rates, and Trends in the Great Lakes. Environ. Sci. Technol.31:2616-2625.

[xi] U.S. EPA. 1997. Recommended Models for USA Pesticide Registration.
http://www.femvtf.com/recommen.htm.

[xii] Reus, J. P. Leendertse, C. Bockstaller, I. Fomsgaard, V. Gutsche, K. Lewis, C. Nilsson, L. Pussemier, M. Trevisan, H. van der Werf, F. Alfarroba, S. Blümel, J. Isart, D. McGrath, T. Seppällä. Comparing Environmental Risk Indicators for Pesticides. http://clm.nl/en/caper.phtml.