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Factors affecting herbicide application rates as reported by no-till corn farmers in nine Michigan counties

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FACTORS AFFECTING HERBICIDE APPLICATION RATES AS REPORTED BY NO-TILL CORN FARMERS IN NINE MICHIGAN COUNTIES

By

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ABSTRACT

HERBICIDE APPLICATION RATES BY NO-TILL CORN FARMERS IN NINE MICHIGAN COUNTIES AND FACTORS INFLUENCING HERBICIDE APPLICATION RATES

By

Ernest Amarachukwu Ndukwe

This study explored herbicide application rates by no-till corn farmers in nine Michigan counties which were the leading no-till corn counties in 1987. Each county had 10,000 or more acres of no-till corn.

The study's purpose was to (1) determine whether or not farmers apply herbicides according to recommended rates on container labels and what factors influence the rates of herbicides applied; (2) determine if the same farmers apply the same rates of herbicides to their no-till and conventional-till corn and (3) the extent that levels of education, land ownership, farming status, environmental awareness, income, farm size, and years in continuous no-till corn influence the rate of herbicide applied by the farmers.

The population consisted of 376 no-till corn farmers compiled from names provided by the District Soil Conservationists in the counties selected. A survey

questionnaire was used to gather information. Ninety-two valid responses were received, resulting in a 30% response rate. There were 72 returned, but invalid, responses.

The survey indicated that all respondents applied herbicides mostly below and within the range of recommended rates. The rates of atrazine, cyanazine, metolachlor, and alachlor applied to no-till and conventional tillage conformed to each other. A t-test analysis evaluated significant differences in the rates of herbicides applied. There were no significant differences in no-till and conventional till. It was also found that level of education, ownership of farmland, farming status, and the farmer's environmental awareness, had no apparent influence on the reported rates of herbicides applied. Finally, the number of years the respondents have practiced continuous no-till corn in most cases did not influence the rates of herbicides applied.

DEDICATED TO MY PARENTS

MR. SILAS A. NDUKWE

AND

MRS. AUGUSTA N. NDUKWE

The older I get, the more I cherish the principles they have always espoused. Those principles are truth, honesty, and goodwill toward everyone.

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Usually in science and in higher education, there is a tendency to be shy in acknowledging God's contribution. However, I believe I have been very fortunate and blessed in so may ways. My middle name (Amarachukwu), when translated from Ibo (a Nigerian language), means God's mercy; God (Chukwu) and mercy (Amara). All of my hard work would have been fruitless without mercy, guidance, and blessing from the Almighty.

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CHAPTER I

INTRODUCTION

Among the environmental concerns recently gaining attention in the United States is groundwater contamination by agricultural chemicals, particularly from pesticides and fertilizers. A report issued by the United States Office of Technology Assessment (OTA) targets groundwater contamination as the primary environmental concern for the rest of the 1980s (Tevis, 1986). The Environmental Protection Agency (EPA) has put pollution by pesticides at the top of its list of most urgent problems. Consequently, the control of pesticides already in commercial use was ranked as the topmost major issue confronting the EPA (Shabecoff, 1986).

Scientists, environmentalists, and the general public are concerned about the public health consequences of pesticides as well as the other environmental effects. Shabecoff (1986) indicated that a number of developments in recent years have added new urgency to the need to regulate pesticides. Among the developments are:

1. The discovery that pesticides are appearing in underground water supplies despite an earlier belief that they would not pass through the soil.

2. The discovery that some poisons registered for use in the past three decades can cause health problems such as cancer, mutations, and birth defects.

3. The discovery of pesticide residue in a growing number of food products.

4. A growing awareness that huge volumes of pesticides are used inside homes, factories, and hospitals, and on lawns and farms, often by people untrained in their use or unaware of their dangers.

5. Complaints that farm workers are still inadequately protected from pesticides and that widespread illness results.

6. The growing export of pesticides, some of which are banned in the U.S., to developing countries where they often are uncontrolled, and may return to the U.S. on imported foodstuffs.

Furthermore, Shabecoff (1986) indicated that the EPA has been able to provide assurances of safety for only 37 of the more than 600 active ingredients used in 45,000 pesticides on the market and that even at a more aggressive pace adopted recently, EPA can only review 25 such ingredients a year.

The farming sector, especially commercial farming, is the largest consumer of pesticides and potentially a primary source of groundwater contamination. Until the 1970's, insecticides constituted the largest volume of pesticides used by farmers. In the early 1980's, herbicides represented 57 percent of the $3.7 billion-a-year pesticide market in the U.S. (Hinkle, 1983; Chemical Week, 1982).

Contamination of groundwater does not occur only through farming activities. It may come from other human activities, such as surface impoundments, landfills, leaks and spills, land disposal of waste waters septic tanks, mining, petroleum and natural gas production, underground injection wells, and other sources (EPA 1977) (see Fig. 1.1).

Groundwater contamination is a major concern in the U.S. because one-half of the population and 90 percent of those who live in the rural areas use groundwater for drinking (D'tri and Wolfson, 1987). In Michigan, about 43 percent of the residents depend on private wells for their drinking water supply (Water Impacts, November/December 1988).

Environmental, health, and other implications of increased pesticide use have been a major reason for the recent upsurge in interest by scientists and

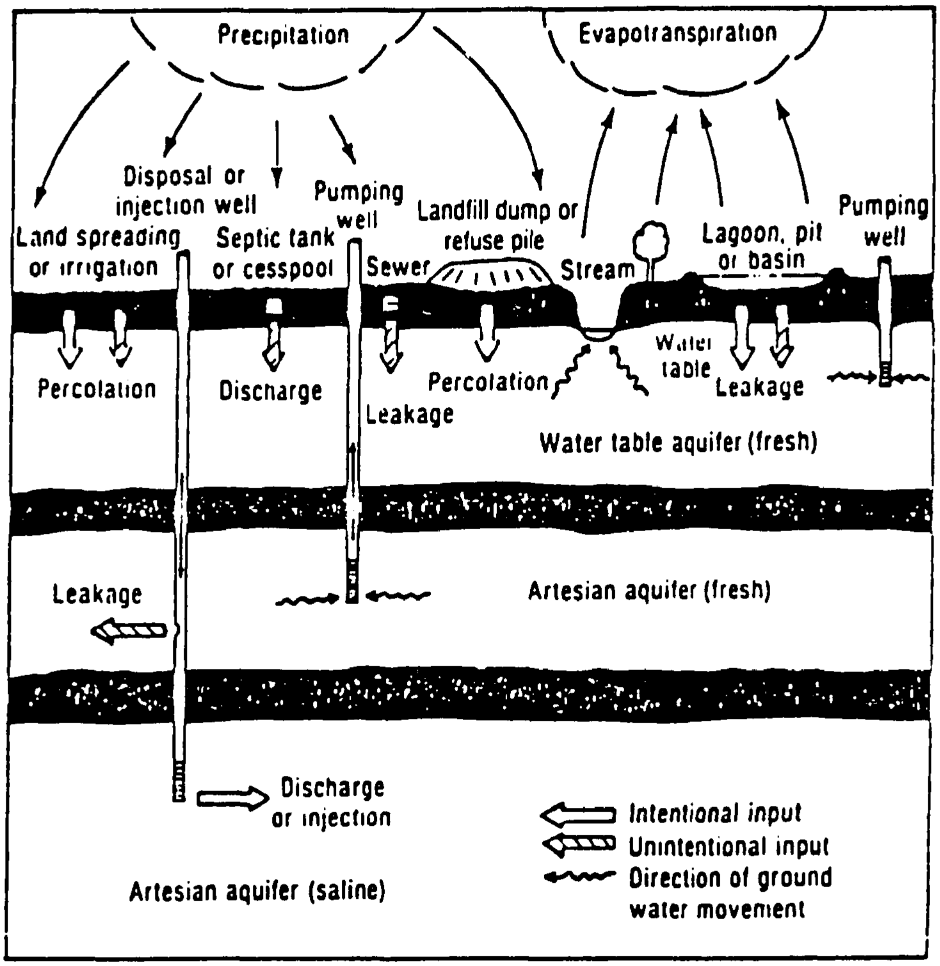


Figure 1.1 Sources of Groundwater Contamination.

Source: Adapted from U. S. Environmental Protection Agency, 1977.

environmentalists for sustainability in agriculture. Sustainable farming systems have been defined to include:

1. Systems that maintain and improve soil productivity, quality, and tilth.

2. Systems that augment the potential for achieving the highest possible efficiency in the use and conservation of basic farm resources (soil, water, sunlight, energy, and farmers' time).

3. Systems that incorporate as much biological interaction as possible: for example, mulching, the use of nitrogen fixing plants, the use of agroforestry techniques, and the use of intercroping and crop rotations to control pests and weeds.

4. Systems that minimize the use of health endangering and environmentally damaging external inputs (some chemical fertilizers, nonselective pesticides and herbicides, and some forms of energy), and maximize instead the use of available affordable, renewable, and environmentally benign inputs, and

5. Systems that avoid the contamination of groundwater by using only those fertilizers, pesticides, and herbicides that do not penetrate below the plants' growing zone and then only in controlled doses (Committee on Agricultural Sustainability, 1987).

Scope of the Problem

Increased use of herbicides is a cause for concern due to potential health problems from direct contact or consumption and potential impacts for surface and groundwater contamination. There is concern for material, labor, energy, and time costs arising from increased herbicide use. There is also the concern for potential crop damage due to excessive herbicide application or misapplication. Hartwig and Hall (1980) noted that pollution of streams, lakes, and adjacent lake areas represent potential contamination problems due to herbicide runoff losses.

Herbicides are one source of nonpoint pollution. Myers et al. (1985) included agricultural, mining, urban, construction, and silvicultural sources as the more important sources of nonpoint pollutants nationally. Myers et al. (1985) further added that although the principal sources of nonpoint pollution vary from region to region and state to state, agricultural sources were identified as the most pervasive nonpoint source pollutants.

> Estimates indicate that more than 100,000 (.08 percent) of the 13 million drinking water wells in the U.S. may have detectable concentrations of pesticides that leach into groundwater. In areas of vulnerable hydrogeology and heavy agrichemical use, as many as 25 percent of wells have detectable levels of pesticides and 10 percent have contamination levels above established health advisory levels (Fleming, 1987).

The Environmental Protection Agency (EPA, 1984) indicated that virtually all states in the U.S. have some water quality problems caused by nonpoint sources. The EPA (1987) also indicated that contamination of the groundwater can occur from pesticide applications to crops and subsequent leaching as well as from chemical spills, accidents, or from aircraft used to spray pesticides.

As shown on Table 1.1, Cohen et al. (1986) reported that "at least" 17 pesticides have been found in groundwater in 23 states as a result of routine agricultural practices.

Table 1.1 Herbicides and States of Detection

Herbicide	State(s)
Alachlor	Maryland, Iowa, Nebraska, Pennsylvania
Atrazine	Pennsylvania, Iowa, Nebraska, Wisconsin, Maryland
Bromacil	Florida
Cyanazine	Iowa, Pennsylvania
Dirosels	New York
Metolachor	Iowa, Pennsylvania
Simazine	California, Pennsylvania, Maryland

Adapted from S. Cohen, C. Eiden, and M. Lorder, 1986.

Kelly et al. (1986) showed that many commonly used pesticides especially herbicides, are leaching into groundwater and that several herbicides, especially atrazine, are persisting in groundwater.

Two separate studies conducted in Michigan revealed the presence of atrazine in groundwater. A study conducted by the Michigan Department of Agriculture (MDA) showed detectable levels of atrazine in 18% of the 50 wells tested. The MDA study investigated "commercial sites where agricultural chemicals are routinely handled and stored" and "where the soil type was conducive to contamination." The MDA study also found nitrates in 25 of the 50 wells tested (GEM Notes 1989, MDA 1989).

In another study, the Institute of Water Research (IWR) at Michigan State University found "detectable levels of atrazine" in 29% of the 38 wells tested. The IWR study was conducted "in predominantly agricultural counties, focussing on areas highly vulnerable to contamination from land use activities" (GEM Notes, 1989). Atrazine and nitrates were tested because they are widely used and because they have been found to contaminate groundwater in other states.

Lee and Nielsen (1987) stated that people who live and consume mostly groundwater where the contamination potential from agriculture is high will likely incur the highest costs. These costs include monitoring and detection activities, adverse health effects, installation of water filters, and the use of bottled water.

Statement of the Problem

A report by the State of Michigan Governor's Cabinet Council on Environmental Protection (1985) stated that approximately 92 percent of Michigan's land area is classified as rural. According to the Report, nearly all water pollution originating from rural land is nonpoint in source and comes from various types of land use activities. The Report further stated that the most serious nonpoint pollution source originates from area of intense agricultural and urban uses and that the most significant pollutants from agricultural sources are sediment, nutrients, and pesticides. Cropland was noted as the major source of these pollutants, especially in areas characterized by high density row crops and fine-textured soils where insufficient attention is paid to soil conservation and drainage practices.

The report by the Governor's Cabinet Council furthermore listed the benefits of nonpoint source pollution control. They include:

1. Protection of soil resources base for food and fiber production
2. Protection of drinking water supplies

3. Protection of aquatic ecosystems
4. Protection of commercial and sports fisheries
5. Enhanced recreational activities
6. Reduced damage to drainage and water treatment facilities
7. Protection of water storage and navigation facilities

A Michigan Department of Natural Resources publication (1986) indicated that nearly one-half of Michigan's residents rely on groundwater as their source of drinking water while many communities, and probably 95 percent of rural families, are served by groundwater wells.

It is well documented that herbicide use was been on the increase over the years. Between 1966-1980, U.S. farmers' purchase of herbicides (pounds of active ingredient) increased by 140% (Eichers, 1981). However, it is not known if farmers are applying herbicides strictly according to recommended application rates on herbicide container labels.

Study Objectives

The primary objective of this study is to determine if no-till corn farmers in nine Michigan counties are applying herbicides according to recommended application rates.

A second objective was to determine if the same farmers apply the same rate of herbicides to both no-till and conventional-till corn acreages. The third objective of this study was to determine whether certain factors, such as income, level of education, farming status, environmental awareness, and land ownership have any influence on the perceived rates of herbicides applied by the farmers.

Research Questions

Based on the study objectives, the consequent research questions are:

1. To what extent do herbicides applied by no-till corn farmers in nine counties of Michigan conform with the recommended rates on container labels?

2. To what extent do herbicide rates applied by the same no-till corn farmers conform with herbicide rates they apply on conventional till corn acres?

3. To what extent does the level of education influence the rate of herbicides applied by the farmers in no-till and conventional till corn?

4. To what extent does ownership or rental of farmland influence the rate of herbicides applied by the farmers in no-till and conventional till corn?

5. To what extent does farming status (full-time versus part-time) influence the rate of herbicides applied in no-till corn?

6. To what extent do farmers' environmental awareness influence the rate of herbicides they applied in no-till and conventional till corn?

7. To what extent does income influence the rate of herbicides applied by the farmers in no-till and conventional till corn?

8. To what extent does the size of the farm influence the rate of herbicides applied in no-till and conventional till corn?

9. To what extent do years in continuous no-till corn influence the rate of herbicides applied?

Organization

In addition to the scope of the problem, study objectives and a description of the area of study previously discussed, Chapter I also includes a definition of terms. Chapter II provides an insight about herbicides and pesticides, their historical development, trends in use, environmental impacts of pesticide use, history and trends in no-till and characteristics of no-till farmers. Chapter II also compares no-till and conventional.

Chapter III outlines the design of the study including the population and instrumentation used in the study. Chapter IV reports the presentation and analysis of data and Chapter V includes the summary, conclusion, discussion, and recommendations for future study.

Significance

This study is significant because it has not been previously determined whether farmers are applying herbicides based on the recommended rates (Nowak, 1987). This study will shed some light on issues such as:

1. what the farmers are doing in terms of the actual herbicide rates they apply (in active ingredients);
2. whether there is a significant difference between the rates of herbicides applied to no-till and conventional-till corn by the same farmers who raise both;
3. where the farmers get their information on the rates of herbicides they apply; and
4. whether the farmers perceive agricultural practices in their locality as a source of environmental and health concerns.

Area of Study

The study area for this research is the southern portion of Michigan's lower peninsula. The study area is composed of nine counties: Berrien, Cass, Clinton, Eaton, Hillsdale, Ingham, Ionia, Isabella, and Lenawee (Fig. 1.2). The population of the counties and their ranks in the state are shown on Table 1.2. These nine counties were chosen because they were the nine primary no-till corn-producing counties in the state in 1986 (Quisenberry, 1987). Each of the nine counties had more than 10,000 acres of no-till corn in 1986.

The major land use in the nine counties are cropland, forest, and other land which includes land in

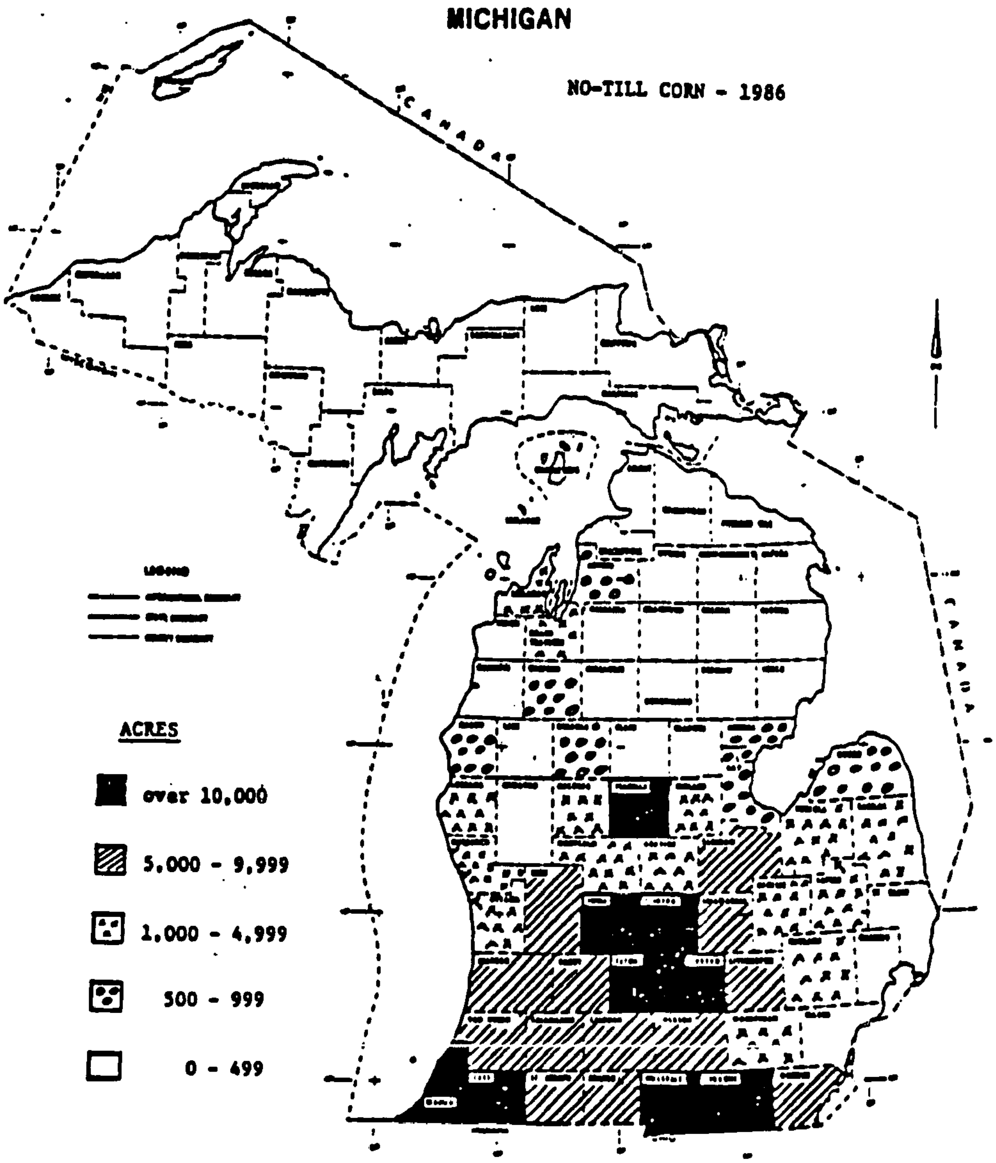


Figure 1.2 The Nine Counties Studied (Shaded in Black).

Source: U. S. Department of Agriculture, Soil Conservation Service, 1987.

Table 1.2. 1987 Population and Size of the Nine Michigan Counties Under Study

County	Population (1987)	County Population Rank in State (83 Counties) (1987)	Rank in Size (83 Counties) (1987)
Berrien	164,800	11	40
Cass	48,300	35	73
Clinton	56,400	29	42
Eaton	91,900	19	37
Hillsdale	42,800	36	36
Ingham	279,600	6	57
Ionia	54,700	31	38
Isabella	53,600	32	39
Lenawee	89,300	20	23

Source: Michigan Department of Agriculture, 1988.

buildings, roads, streets, wasteland, and noncommercial forest (MDA, 1988) (see Table 1.3). Cropland is least in Berrien County (39.8 percent) and highest in Lenawee county (66.7 percent) among the nine counties.

The topography of most of the counties, including Hillsdale, Lenawee, Berrien, Cass, Clinton, Eaton, Ingham and other counties in Southwest Michigan are characterized by "glacial features and drainage systems with the highest elevations associated with recessional and interlobate moraines, and the lower elevations with outwash channels, outwash plains, lake plains, and till plains" ("Hydrogeology for Underground Injection Control," 1981). The range of elevations in the region is from 577 feet on Lake Michigan to about 1282 feet at Budday Hill in Hillsdale County. The hydraulic characteristics of glacial drift aquifers result in well depths ranging from 18 feet in Van Buren County to 422 feet in Ingham County. The hydraulic characteristic of bedrock aquifers in the region indicate that Pennsylvanian aquifers dominate most of the region and supply the largest number of bedrock wells ("Hydrogeology for Underground Injection Control," 1981). The depth of bedrock wells in the region range from 46 feet in Lenawee County to 525 in Clinton County ("Hydrogeology for Underground Injection Control," 1981).

Table 1.3. Land Use (1982) in Nine Michigan Counties Under Study

County	Total County Acreage (in Acres)	Cropland	Pasture	Forest	Water	Other Land
Berrien	368,704	39.8	2.6	17.9	0.7	39.0
Cass	317,580	43.8	6.6	17.0	2.9	29.7
Clinton	366,764	58.1	3.8	8.3	0.3	29.5
Eaton	370,745	48.9	5.7	12.3	0.2	32.9
Hillsdale	385,862	51.0	5.2	11.7	0.6	31.5
Ingham	358,214	49.1	3.8	11.8	0.2	35.1
Ionia	369,299	50.5	5.2	10.1	0.6	33.6
Isabella	369,017	40.6	5.5	21.2	0.2	32.5
Lenawee	481,625	66.7	3.1	9.9	1.2	19.1

Source: Michigan Department of Agriculture, 1988.

The average annual monthly temperature of the nine counties under study is 48 F. The average annual precipitation, which is subdivided into rainfall and snowfall, is 34 inches and 46 inches, respectively for rainfall and snowfall in the nine counties ("Climate of Michigan," 1974) (see Table 1.4).

Table 1.4. Average Annual Temperature and Precipitation Based on a 30-Year Record (1940-1969)

County	Temperature	Rainfall	Snow, Ice Pellets
Berrien	49.4	35.7	57.8
Cass	49.4	36.8	63.3
Clinton	47.7	30.3	37.4
Eaton	47.8	32.4	38.3
Hillsdale	48.1	36.5	52.7
Ingham	47.4	30.9	38.8
Ionia	47.7	30.6	39.7
Isabella	49.4	35.6	57.8
Lenawee	48.9	32.7	30.3
AVERAGE	48.0	34.0	46.0

Source: Climate of Michigan, 1974.

Definition of Terms

In order to aid those readers who are unfamiliar with some of the words or terminology used in this study, the following definitions have been provided.

Conventional or Clean Tillage

The combined primary and secondary tillage operations normally performed in preparing a seedbed for a given crop growing in a given geographical area (Resource Conservation Glossary RSG, 1982).

Conservation Tillage

Any tillage sequence that reduces loss of soil or water relative to conventional tillage, often a form of noninversion tillage that retains protective amounts of residue mulch on the surface.

Herbicide

A chemical used to control, suppress, or kill plants, or to interrupt severely their normal growth processes (Ross and Lembi, 1985).

Goulding (1985) descriptively defined herbicides as those products intended, or employed, for the purpose of destroying or inhibiting the growth of plants.

No-Till or Zero Tillage

A method of planting crops that involves no seedbed preparation other than opening the soil for the purpose of placing the seed at the intended depth (RCG, 1982).

Pesticide

Any chemical agent used for control of specific organisms, such as insecticides, herbicides, and fungicides (RCG, 1982).

CHAPTER II

HERBICIDES/PESTICIDES

Historical Development

Ware (1983) noted that the earliest record of any material being used as a pesticide is by Homer, the Greek poet, who referred to the burning of sulfur for fumigation of homes in about 1,000 B.C..

Ross and Lembi (1985) indicated that weed control technology had its beginnings about 1900 and

> although salt, ashes, smelter wastes, and other industrial byproducts had been applied for centuries at high rates (and near their source of supply) to control vegetation, it was the discovery of the fungicidal properties of Bordeaux mixture that led to the first serious attempts at chemical weed control. The discovery (near Bordeaux, France) in 1896 that a lime-copper-sulfur mixture would control downy mildew on grapes led to the extensive testing of this fungicide and other copper salts for the control of diseases on a variety of crops. A major development effort occurred from 1900 to 1915 in France, Germany, and the United States with most of the emphasis placed on weed control in cereal crops.

According to the National Research Council (1968) solutions of copper nitrate, ammonium salts, sulfuric acid, iron sulfate, and potassium salts were shown to be selective herbicides. Ross and Lembi (1985) noted that the development and extensive use of selective chemical controls lapsed after 1915 in the United States while they were used extensively in Europe and the British Isles. The prevalence of small, intensively cultivated farms which insured that the chemicals would be applied in a timely and careful manner was seen as the reason for the extensive use in Europe. In addition, Ross and Lembi (1985) noted that "the penetration and effectiveness of these water soluble salts were favored by the high humidity conditions prevalent in these areas." Crafts (1975) suggested the lapse in the U.S. of the chemicals after 1915 to inadequate spraying equipment, large acreages, low humidity conditions, and the introduction of cleaner, weed-free seeds and effective fallow systems.

A limited number of herbicides were introduced between 1900 and 1940 (Ross and Lembi, 1985). These herbicides included persistent compounds, such as the arsenicals, chlorates, and borates as long residual herbicides; carbon bisulfide and the thiocyanates as fumigants; ammonium sulfamate for the control of woody plants; selective and nonselective herbicidal oils, and the dinitrophenols, the first specific group of organic compounds to be used for weed control. At the start of World War II, then, the list of available herbicides consisted of about a dozen chemicals of somewhat limited utility.

According to Ross and Lembi (1985), the development of modern herbicide technology was triggered by the discovery of the herbicidal properties of 2,4-D (2,-3-dichlorophenoxyacetic acid). The herbicide was synthesized in 1941. The compound was released for general investigation and use after World War II. It was found to be effective at low rates (1/4 to 4 lb./acre), cheap to produce, and had a broad spectrum of uses. In addition, "the commercial success of 2,4-D provided the incentive for the development of several hundred chemical compounds currently available for weed control."

Trends in Use (Pesticides)

The use of pesticides has been on the incline since the discovery of 2, 4-D and since the end of World War II. Eichers (1981) noted a 140% increase (in pounds of active ingredient) in the purchase of pesticide by U.S.A. farmers between 1966-1980. Maddy (1983) wrote that there has been a substantial increase in "the number of pesticide products used, the individual active ingredients in pesticides and the total poundage of pesticides used." Maddy (1983) added that "more than 45,000 individual pesticide products containing more than 1,500 active ingredients, and many times that number of so-called 'inert' ingredients" were registered for use in the U.S.A.

Furthermore, Maddy (1983) attributed the rapid growth in use of pesticides in the U.S.A. between 1966-1980 to

> pesticide prices which rose only half as much as other inputs, farmers' felt need to protect the increasing investment required in producing a crop and due to the increased use of multi-chemical products, tank-mixes, and multiple sequential applications to obtain season-long weed control and the control of problem weeds.

Wolcott (1988) noted that the use of pesticides, virtually nonexistent prior to World War II, has burgeoned into a $4.5 billion industry (in the U.S.). Wolcott furthermore stated that in 1986, more than 500 million pounds of agricultural pesticides were used in the U.S. The great majority of agricultural chemical use is for the purpose of sustaining yields of the basic commodity crops supported by the U.S. government's farm program. Corn, for example, accounts for more than 30 percent of all agricultural pesticide use. Six basic commodity crops--corn, wheat, rice, cotton, barley, and soybeans--all of which have some kind of U.S. Department of Agriculture (USDA) price support or loan program, account for a combined total of more than 80 percent of the total volume of agricultural pesticides. In addition to growth in the use of agricultural chemicals on the USDA program crops, there has also been a sharp increase in the kinds and amounts of chemicals used on specialty crops (fresh produce and fruits in particular). A wide variety of chemicals have been developed, not only to combat pests and plant diseases, but also to regulate the growth of fruits and vegetables and enhance the cosmetic appearance of produce.

A report by the EPA (1987) showed that about 552 million pounds of active ingredients were applied to major field crops in 1982 and approximately 280 million acre treatments are conducted annually (EPA, 1987).

D'ltri and Wolfson (1987) also noted that the annual total output of pesticides in the U.S. is more than 2.5 billion pounds with 1,500 active ingredients in some 45,000 products.

In terms of pesticide use, Schaub (1985) wrote that:

> historically, a common measure of pesticide use has been pounds of active ingredient (a.i.) applied. Another is number of acres treated and a third is acre-treatments (which is the average number of times a pesticide is applied to a given acre times the number of acres treated. The fourth measure of importance is expenditures for pesticides. With the development of new products requiring application rates as low as 0.1 lb. (a.i.) per acre, pounds applied, when used for historical comparisons, is losing meaning unlike the more meaningful measures such as of acres treated. . . .

The use and increased use of farm chemicals, such as pesticides, relates to the need to increase the world food production for the ever-growing world population. Koeman (1985) acknowledged that there are, in general, two ways to achieve an increase in agricultural production. One method is by increasing the acreage of arable land,

and secondly, by intensification of production per unit area.

Ahrens and Cramer (1985) implied that pesticides have been used to counter fluctuations in agricultural production. Ahrens and Cramer (1985) also noted that inclement weather and pests are two main factors that can be considered responsible for great fluctuation of production in agriculture. However, while inclement weather is beyond human control, humans have been fighting against pests, and it is only in the last 50 years, with modern plant protection technologies, that humans have been successful in bringing the greatest problems under control.

Economic Importance of Pesticides

Yield losses can be both quantitative and qualitative. An initial global estimate of the quantitative losses for 60 important crops made in 1967 concluded that about 35 percent of the potential yield was lost through plant pests, such as insects, fungi, and weeds (Crammer, 1967).

With a 30 percent reduction of pre-harvest losses caused by animal pests, plant diseases, and weeds in developing and centrally planned countries, alone, it has been estimated that 100 million tons of additional grain would become available (Buchel, 1983).

The quality of the agricultural product is of a major concern to the farmer and the consumer. To the farmer, it is an issue of marketability of the product, especially of fresh products, such as fruits and vegetables. The farmer is concerned about the marketability of the product because the consumer or the processor is very particular about the quality of the goods which, as a rule, is evaluated with respect to size, perfection, and cleanliness of surface or substances contained, such as starch, oil, sugar, and aroma (Ahrens and Crammer, 1985).

For the most part, quality criteria is realized only through the use of plant protection chemicals, such as insecticides, fungicides, molluscides, nematicides, and herbicides for the prevention of direct and indirect damage, such as the reduction of storage life (Ahrens and Cramer, 1985).

In an experiment done in apple orchards, it was shown that the deficit or the insufficiency of crop protection measures had a negative impact on the yield and marketability of the fruit. Without plant protection measures, the yield declined to 57 percent of what would have been realized with a full-season program, while the percentage of the fruit which, on the basis of quality criteria, could be graded as marketable, dropped to only

19 percent of the possible total yield (Kolbe, 1982, 125-33).

Pesticides can serve as a means to improve existing crop production systems, and even to create, under particular circumstances, new crop production techniques (Ahrens and Cramer, 1985). For example, the production of sugar beets used to be very labor-intensive because weed competition had to be eliminated over a long period between seed germination and complete leaf-coverage of the soil. Previously, it required 130 human labor hours per hectare from drilling to harvest of which more than 100 hours were required for weeding alone . With chemical weed control practices today, coupled with new equipment, it requires less than 30 hours to grow one hectare of sugar beet (Ahrens and Cramer, 1985). Consequently, the use of pesticides appears to save time and labor costs.

Ross and Lembi (1985) outlined the contributions of herbicides which are the most widely used pesticides. The contributions are:

1. herbicides permit the control of weeds where row cultivation is impossible,

2. herbicides reduce the number of tillage operations, as well as the critical timing needed for such operations, particularly at planting time,

3. herbicides have reduced the amount of human effort expended in handweeding and consequently reduced weeding costs where effective herbicides are applied,

4. weeds not economically controlled by other methods frequently can be controlled effectively and at relatively low cost with herbicides, and

5. the use of herbicides has permitted greater flexibility in the choice of a management system. Consequently, farmers today can use fewer crops in rotation, have the option of removing one or more tillage or mowing operations, and eliminate periodic fallow every three or four years.

In the 1960's, it was estimated that a $1 expenditure on pesticides brought a $4 return in the aggregate (Headley, 1968). Unlike previous studies, recent studies point toward a decline in the returns to pesticide use. A study showed that of every $1 spent for herbicides and insecticides in corn production, the returns were only $1.50 and $1.30, respectively (Hanthorn and Duffy, 1983). It was concluded that as farmers use more pesticides, returns to expenditure decline. Returns have not equalled costs in some instances. Over-application of pesticides have been attributed as the reason, in addition to changes in pest populations and pest resistance (Schaub, 1985).

Economic Impact of Restricting Pesticide Use

For the purposes of this study, restricting pesticide use ranges from regulation to restricting the use of one pesticide to a specific use to a total ban of all pesticides for all uses.

Between late 1970s and mid-1980s, 25 studies were completed, representing about 35 registered pesticides which is a small portion of the total number of registered chemical pesticides. It was estimated that the economic impact on producers and consumers would have been in excess of $6 billion annually if all uses of these pesticides had been cancelled (Schaub, 1985).

Pesticide regulation alone adds up to high private and public costs. In 1975 the private cost to discover and develop a pesticide was nearly $15 million (Schaub, 1985). For the same period (1975), it was estimated that funds available for research and development (R and D) were $320 million annually, of which about 60 percent was available for new product development, with the remainder used to maintain the registration and marketability of previously registered products (Schaub , 1985).

In 1983 it was estimated that industry spent $450 million annually for research and development (Pliszka, 1983). The increase in research and development expenditures was attributed to the revenue-making capability of the industry and in 1981 it was estimated that 67 percent of the expenditure was invested into new product development (Pliszka, 1983). Over the past 15 to 20 years, it has become increasingly evident that registration and environmental testing do comprise a significantly larger proportion of the R and D expenditures (Schaub, 1985).

To ascertain public costs of regulation is extremely difficult. Nonetheless, it is agreed that public costs of regulation is high. The financing of the pesticides program in Environmental Protection Agency (EPA) is estimated to be around $28 million in fiscal year (FY) 1983, down from about $31 million in FY 1982 (Office of Management and Budget, 1982). However, within the EPA budget was some $230 billion for Management and Support, some of which presumably will be allocated to the pesticide programs (Schaub, 1985).

One study estimated that banning the use of 2, 4, 5-T on 8 million acres of farm and nonfarm land in 1969 would have increased costs to farmers about $32 million, assuming the level of production at the time was maintained (Fox, 1972). It was also estimated that it would have cost farmers $44 million to replace 2, 4, 5-T (Fox, 1972).

It has been shown that the effect of restricting use of herbicides is a rise in costs, although the total dollar effect on individual farmers depends on the demand for individual products and on whether or not there are government programs (Fox, 1972). Fox (1972) indicated that:

> for purposes of budgeting effects of banning herbicides, changes in the marginal costs (incremental costs) are particularly important because this cost curve above the minimum average variable cost is, in effect, a supply curve (lines drawn from any point on this curve horizontally or vertically to the price and quantity line show prices associated with quantities sold). Increases in the marginal cost for an individual farmer are the same as a decrease or shift to the left in the supply curve for the given product.

(See Figure 2.1) Consequently, farmers will produce less at the same price because of increased costs and because of higher costs, some farmers would also go out of business (Fox, 1972).

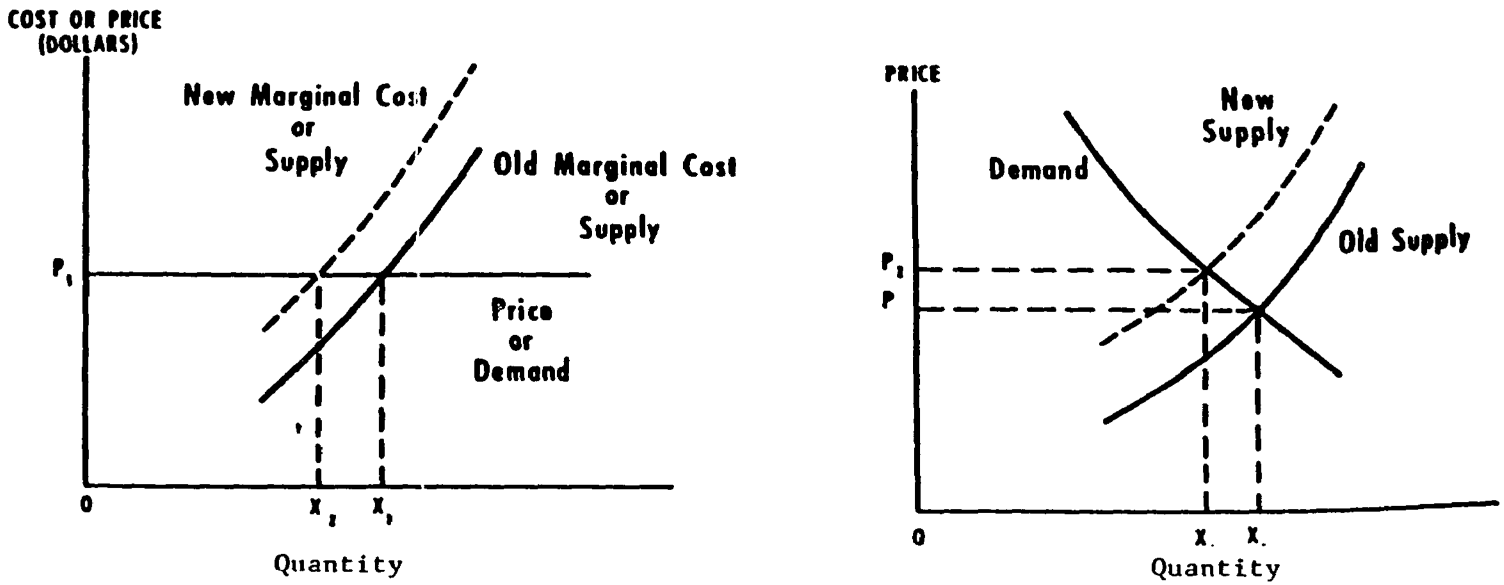
Cashman et al. (1981) concluded that "herbicide bans under typical Indiana conditions would inflict substantial, short-run economic losses on individual farmers" since "a simultaneous ban on all dinitroaniline, triazine, and amide herbicides reduced corn and soybean yields 14 and 17%, respectively and net farm income by 65%." Such reductions were blamed on "harvest delays attributable to less effective weed control" which "resulted in a loss in efficiency, yields, and profits, and increased machinery and labor requirements."

The industry or market supply curves are generally similar to the individual farm supply curves, but totally different from the demand curve for individual farmers since the market demand curve is negatively sloped and generally inelastic (Figure 2.1). As a result of the change in supply and the sloping demand curve for farm products, reductions in supply (X_1 to X_2) will result in higher prices paid for farm products (P_1 to P_2).

Fox (1972) postulated that with lower food production and higher prices, farmers would often get more than they got before restriction since the demand for food is inelastic as there are not good substitutes for food.

Dailey (1974) similarly discussed the effects of restricting or banning use of pesticides on the producers, the industry, the consumers, and general effects. Farmers would likely receive more for their agricultural commodities than they received before a restriction because the demand for food is inelastic. Thus, the increase in prices would more than offset any decline in production. However, for commodities characterized by elastic demand, the increase in price would not be enough to offset the loss in production (Dailey, 1974).

Dailey (1974) acknowledged that for the industry, restricting the use of pesticides would generally raise production and distribution costs for pesticides because of generally higher costs brought about by a reduced



By Individual Farmer

For All Farmers

Figure 2.1 Effect of Higher Costs on Supplies and Price, Without Support Prices and Acreage Restrictions

Source: A.S. Fox, "Economic Impacts of Restricting Herbicide Use." Journal of Environmental Quality 1(4) (1972): 439.

volume of production. It was further indicated that some companies would lose and others would benefit. Although, in general, pesticides comprise a small portion of the business of most manufacturers. Consequently, losses and gains would be small in comparison to total sales.

The effect on the consumer of restricting the use of pesticides was seen as higher costs for food and fiber. With regard to the general effects of restricting or banning the use of pesticides for selected crops in specific areas, the impact was seen as resulting to some regional shifts in production. In an example, Dailey (1974) indicated that

> long run adjustments from banning organochlorine could lead to higher costs of producing cotton particularly in the southeast. This, plus the continued pressure from synthetics, might make the production of corn, soybeans, and cattle or increased timber production more attractive in this region. If the use of organocholorines were banned, the inducement to grow corn in the south could be further increased because of possible insect problems in the Corn Belt.

Two events in March, 1989, in the U.S. brought national and international attention to the dangers of pesticides in agricultural products. In the first week of March, 1989, the Natural Resource Defense Council (NRDC) reported that apples treated with the growth regulator and ripening agent, Alar, were endangering small children with dangerously high levels of daminozide, a possible carcinogen (Carson, 1988). Less than a week later, two grapes imported from Chile were found to be laced with cyanide. The Food and Drug Administration (FDA) warned consumers not to eat grapes, or any other fruit from Chile. Following the warning, fruits including grapes, most of the peaches, blueberries, blackberries, raspberries, melons, pears, plums, and nectarines disappeared from fruit markets and the grocery stores across the U.S. About the same time, 400,000 chickens were destroyed in Arkansas because they were found to be contaminated with heptachlor, which is an outlawed pesticide (DeVault, 1989).

The warnings from the NRDC and FDA highlighted the potential health hazards of pesticide use. Although cyanide is not a pesticide used in the agricultural sector, the scare from the two grapes laced with cyanide reminded the general public and the federal government, in particular, about proper monitoring of agricultural products, especially imported fruits and vegetables. Long before the incident involving the cyanide-laced grapes, American consumers have often suspected a higher-than-allowed levels of pesticide on imported agricultural products. Such suspicions have often been heightened on American television where imported agricultural products have been portrayed by some advertisers as travelling less than desirable routes and being indiscriminately sprayed with pesticides. It is interesting to note that Uniroyal

Corporation, the manufacturer of Alar, decided to stop the production of Alar for use in the U.S. in May, 1989, due to the controversy surrounding the chemical. However, no such categorical statement was made regarding its export or production overseas.

Although the television advertisement about imported food items borders on sarcasm, data indicate that there are reasons to be wary or somewhat wary. Acknowledging that pesticide pollution does not respect national borders, Weir and Shapiro (1981) noted that approximately 10 percent of imported food in the U.S. contains illegal levels of pesticides and that although some hazardous chemicals have been banned in U.S., Americans are not escaping the harmful effects (Table 2.1). The General Accounting Office (GAO) (Eschaege, 1978) indicated that the Food and Drug Administration's (FDA) most prevalently used analytic techniques does not even check for 70 percent of about 900 food tolerances for cancer-causing pesticides.

Environmental Impacts of Pesticide Use

Historically, a great deal of emphasis was placed on the economic aspects of pesticide use. The farmers' primary concern has always been to raise farm productivity and yields and to make profits. The consumer, on the other hand, has always been interested in purchasing the product at an affordable (low) price. More importantly, the consumer always wants to know that the agricultural commodity is available and that there is no scarcity (which results in higher prices). The outcome of this farmer-consumer-consumer-farmer interaction is that much attention has been paid to yields, profits, and quality of the products without much thought to the environmental and other consequences of pesticide use. Pesticides have been used to ensure protection against pests and to enhance the cosmetics of the products.

In 1962, Rachael Carson (1962) alerted her readers about the dangers of chemicals in the book the Silent Spring. Almost three decades later, the warning generated in the book is very much as applicable in today's society. In fact, it seems at times that the warning by Carson has gone unnoticed. Except for the banning of DDT in the U.S., there appears to be no other drastic changes since the early 1960s. More pesticides are in use today than in the 1960s, and unlike in the 1960s, herbicides, rather than insecticides, are the dominant pesticides used. Between 1964 and 1985, farmers' use of pesticides more than tripled and today, more than 91 percent of the U.S. row crop acreage and 44 percent of the U.S. small grain crop acreage have herbicides applied annually (Batie, 1988).

Table 2.1. Pesticides Used in Foreign Countries on Food Exported to the United States

Commodity	Countries Surveyed	Allowed Recommended or Used in the U.S.	Any Residues Prohibited (no U.S. Tolerance)	Not Detectable with FDA Tests
Bananas	Colombia Costa Rica Ecuador Guatemala Mexico	45	25	37
Coffee	Brazil Colombia Costa Rica Ecuador Guatemala Mexico	94	76	64
Sugar	Brazil Colombia Costa Rica Ecuador Guatemala India Thailand	61	34	33
Tomatoes	Mexico Spain	53	21	28
Tea	India Sri Lanka	24	20	11
Cacao	Costa Rica Ecuador	14	7	7
Tapioca	Thailand	4	4	1
Straw-berries	Mexico	13	--	5
Peppers	Mexico	12	--	4
Olives	Italy Spain	20	14	8
Totals		340	201 (59%)	198 (58%)

Source: Weir and Shapiro (1981).

The FDA (1978) has shown that more than 15 percent of the beans and 13 percent of the peppers imported from Mexico were in violation of FDA pesticide residue standards at one time. Similarly, nearly one-half of the green coffee beans imported contained traces of banned pesticide residues (Table 2.2) (FDA, 1988). Pesticide contamination has also been observed in imported beef resulting in the suspension of beef imports, such as from Mexico (Mitchell, 1979).

Like the discovery of pesticides in food items, more and more pesticides today are being discovered in both groundwater and surface water. However, unlike the tainted grapes and pesticide-laden food items, groundwater contamination, in particular, by pesticides raises a unique problem and concern. The uniqueness is characterized by the fact that the problem is "unseen" or "invisible." It is a problem which fits the cliche of "out of sight, out of mind." The cliche explains why the problem of groundwater contamination by pesticides and nitrates have gone unnoticed for so long. In her book Carson (1962) wrote,

> The problem of water pollution by pesticides can be understood only in context as part of the whole to which it belongs--the pollution of the total environment of mankind. The pollution entering our waterways comes from many sources: radioactive wastes from reactors, laboratories and hospitals; fallout from nuclear explosions;

Table 2.2. Pesticides in Imported Coffee Beans (1974-1977)

Country of Origin	No. of Samples	No. with Residues
Angola	1	1
Brazil	2	2
Colombia	21	5
Costa Rica	2	0
Dominican Republic	1	0
Ecuador	10	6
El Salvador	2	1
Guatemala	5	2
Haiti	1	1
Honduras	2	1
India	4	4
Indonesia	1	1
Ivory Coast	2	1
Kenya	1	0
Mexico	5	4
New Guinea	2	1
Nicaragua	2	0
Panama	1	0
Peru	5	2
Rwanda	1	1
Uganda	1	1
Venezuela	2	1
Total (22)	74	35

Percentage Contaminated: 48.3%
Pesticides Detected: DDT, DDE, BHC, Lindane, Dieldrin, Heptachlor, Diazinon, Malathion

Source: Weir and Shapiro, 1981.

> domestic wastes from cities and towns; chemical wastes from factories. To these is added a new kind of fallout--the chemical sprays applied to croplands and gardens, forests, and fields. Many of the chemical agents in this alarming melange imitate and augment the harmful effects of radiation, and within the group of chemicals themselves there are sinister and little-understood interactions, transformations, and summations of effect.

Cohen et al. (1986) noted that "at least" 17 pesticides were found in groundwater in 23 states because of agricultural practices (Table 2.3, Hallberg, 1987). The largest number of pesticides were detected in California, New York, and Iowa because there were more monitoring activities in those states.

Aldicarb and other pesticides were detected in groundwater in Suffolk County, New York. The primary factors attributed to the presence of aldicarb in groundwater in Suffolk County "include the pervasive and high rates of use of aldicarb, its high water solubility, heavy spring rainfalls following application, very permeable soils typical of glacial outwash deposits, cold soil temperature, acid soil conditions, low organic matter content, shallow water table conditions, and the presence of many shallow wells immediately down gradient of treated fields" (Holden, 1986).

Pionke et al. (1988) detected concentrations of atrazine in 14 of the 20 wells tested "suggesting widespread atrazine contamination of the groundwater at

Table 2.3. Typical Positive Results of Pesticide Groundwater Monitoring in the U.S.

Common Name Active Ingredient	Typical Concentration g/l	Number of States
Herbicides		
Alachlor	0.10 - 10.0	4
Atrazine	0.3 - 3.0	5
Bromacil	300	1
Cyanazine	0.1 - 1.0	2
DCPA (and Acid Product	50.1 - 700.0	1
Dinoseb	1.0 - 5.0	1
Metolachlor	0.1 - 0.4	2
Metribuzin	0.0 - 4.0	1
Simazine	0.2 - 3.0	3
Insecticides and Nematicides		
Aldicarb (sulfoxide and sulfone)	1.0 - 50.0	15
Carbofuran	1.0 - 50.0	3
DBCP	0.2 - 20.0	5
1,2-DCP	1.0 - 50.0	4
Dyfonate	0.	1
EDB	0.05 - 20.0	8
Oxamyl	5.0 - 65.0	2
1,2,3-Trichloro-propane (impurity)	0.1 - 5.0	2

Source: Cohen et al., 1987

extremely low concentrations." Similarly, Simazine was found in 35% of the wells "at very low concentrations."

Dibromochloropropane (DBCP), a nematicide, was detected in more than 2,000 wells and was known to have contaminated groundwater in a 7,000 square mile region of the San Joaquin Valley in California (Holden, 1986). DBCP was used in California from the 1950s until the registration was cancelled in 1977. Its manufacturers announced that the pesticide was found to cause sterility in male workers involved in its manufacture (Ware, 1983). Aldicarb, alachlor, and other pesticides have also been detected in Wisconsin and Florida (Holden, 1986).

Samples from more than 700 wells in Iowa and 500 wells in Minnesota indicated that between 33 and 38 percent of all the wells tested showed pesticide residues (Table 2.4) (Hallberg, 1987).

Hallberg (1987) inferred that many of the most common pesticides, especially herbicides, are leaching into groundwater and that several of the herbicides are persisting in subsoil and/or groundwater throughout the year.

On-site and off-site environmental problems have resulted from pesticide application. On-site, insects, fungi, nematodes, weeds, and other pets have resurged and become resistant to chemical pesticides and offsite, agricultural chemicals have not only disrupted adjacent

Table 2.4. Pesticides Detected in Groundwater Supplies in Iowa and Minnesota

Common Name Active Ingredient	Maximum Concentration g/l Iowa/Minnesota	Percent of Detections % Iowa/Minnesota
<u>Herbicides</u>		
Alachlor	16.6/ 9.8	15/11
Atrazine	21.1/42.4	72/72
Chloramben	1.7/N.D.	<1/0
Cyanazine	13.0/ 0.10	12/1
Dicamba	2.3/ 2.1	2/2
Metolachlor	12.2/ 2.1	10/2
Metribuzin	6.8/ 0.78	0/2
Picloram	N.D./ 0.13	0/1
Propachlor	1.7/ 0.52	1/3
Simazine	N.D./ 2.6	0/<1
Trifluralin	0.2/N.D.	1/0
2,4-D	0.2/ 4.2	<1/2
2, 3, 4-TP	N.D./ 0.26	0/1
<u>Insecticides and nematicides)</u>		
Aldicarb	N.D./30.6	0/<1
Carbofuran	0.06/N.D.	2/0
Chlorpyrifos	0.07/ 0.21	<1/2
Fonofos	0.90/N.D.	1/0
Phorate	0.10/N.D.	<1/0
Terbufos	12.0 / 0/63	2/<1

<u>Note</u>: N.D. = Not Detected

Source: Hallberg, 1986.

and even distant ecosystems but have also destroyed sensitive nontarget crops (Hinkle, 1985).

Koeman (1985) noted that the injudicious use or deliberate misuse of pesticides, especially in certain tropical countries, have been largely responsible for some cases where there have been large-scale mortality of economic species, such as fish and edible crustaceans. Similarly, damages have been done to pollinating insects. It was also suggested that the presence of pesticides in water systems may depress the populations of aquatic invertebrates that form an important source of food for fish and wildlife (Koeman, 1985). In addition to the potential damage to economic species, pollinating insects, and aquatic invertebrates, it has also been suggested that pesticides may have profound effects on the animal and plant communities in the soil (Koeman, 1985). Snider et al. 1985) found that the total population of springtail fauna decreased temporarily after paraquat was applied. Soil fauna was noted as having economic importance as pests and as being important in other areas, such as in the processing of litter, increase in soil porespace and as food sources for other organisms (Snider et al., 1985).

Grant and Payne (1982) determined the effects some herbicides and insecticides on the process of denitrification in salt marsh environments. The study showed that one of the insecticides, dalapon at a concentration of 10ug/ml clearly inhibited denitrification.

Several field studies reveal the presence of pesticides in subsurface and surface environments. Traces of atrazine ranging from 0.2 to 0.8 ppb was found in the corn-producing areas of Nebraska and leaching from the use of atrazine was determined as the cause (Wehtje, et al., 1981).

Harris (1967) determined in a soil column system that the aromatic acid herbicides were most mobile while the insoluble toluidines were least mobile.

Wu et al. (1983) detected atrazine more frequently and in greater concentration than alachlor and also found that runoff waters from forest watersheds were contaminated with herbicides in areas where herbicides were not directly applied.

Hall (1974) found greater residues of atrazine and GS13529 in soil sediment than in runoff water. The analysis revealed an average of 35.3 percent of the applied atrazine was recovered one month after application.

Nash (1968) determined the synergistic impact of a herbicide and an insecticide. It was found that the combinations of diuron with disulfoton or phorate in the soil resulted in synergistic phototoxicities which persisted in the soil for several weeks.

Volatilization of pesticides from target areas of soil and foliar surfaces present a unique problem. Helling (1987) noted that volatilization seems to have received less research attention than other aspects of pesticide fate in conservation tillage systems partly because of the more complicated field sampling equipment needed and partly because of some difficulty in accurately estimating total pesticide loss. Nonetheless, an appreciable amount of pesticides is lost through volatilization.

Taylor (1978) indicated that the amount of pesticide that volatilizes is usually larger than the pesticide that is lost through leaching or runoff and that volatilization, for most pesticides, is second only to degradation in causing dissipation from a treated field. Similarly, Shoemaker and Harris (1979) noted that with aerial application of pesticides, the amount transported to nontarget areas by air may be as much as several hundred times as large as the amount transported by runoff.

An important aspect of pesticide, particularly pesticide misuse and overuse with environmental implications, is the resistance of pests to pesticides. Sommers (1986) noted that:

> since the early 1900s, about 450 different insects have been resistant to one or more insecticides. Of these, 60 percent are important in agriculture. Adding to this concern, the number of resistant bugs has about doubled from 1970 to 1980 and the number of species adapting to some chemical group has increased 17 times. During the same period, more than 150 herbicide-resistant weeds, at least 100 species of plant disease pathogens and two species of nematodes have been identified as resistant to one or more pesticides.

Resistance of pests to herbicides have been recorded mostly in the U.S., Canada, southern parts of western Europe, Japan, Hungary, and Egypt (LeBaron, 1982). The countries affected are characterized by high levels of herbicide use, often the same or similar herbicides used frequently, and monocultures or limited crop rotations (LeBaron, 1982).

Pesticide use and misuse present potential and real health concerns. The effects of pesticides, plus the interaction between pesticides and other agricultural chemicals in groundwater and the environment is still largely unknown. Hallberg (1987) acknowledged that the unknown effects of the interaction between pesticides and other agricultural chemicals in groundwater raises the issue of uncertainties which exist about the potential long-term, chronic health effects, such as cancer and immune system disorders.

Studies in Iowa and Nebraska (Blair & Thomas, 1979; Burmeister et al., 1983) have shown that mortality from some cancers is significantly higher in rural families. Excessive mortality from Leukemia, multiple myeloma, and non-Hodgkin's lymphoma has shown some consistent associations with herbicide use.

The herbicide, 2, 4-D has been linked to cancer in a study in Kansas (Hoar et al., 1986). The study showed that "farmers exposed to 2, 4-D for more than 20 days a year are six times more likely to develop non-Hodgkin's lymphoma (NHL), a tumor of the lymph system, than nonexposed farmers."

Preliminary research involving more than 2,000 people showed that farmers who used pesticides in the 1950's and 1960's may run a greater risk of developing certain kinds of cancer, particularly leukemia and lymphoma (Allen et al., 1986).

Tevis (1988) noted studies in Nebraska and Kansas which appeared to link 2, 4-D and non-Hodgkin's lymphoma. Leukemia was found to be 35 percent more prevalent in farmers, while lymphoma was 29 percent more among farmers than the general population.

There are other pesticide-related problems, particularly the misuse of pesticides. The number of pesticide-related accidents and fatalities have been on the decline in the U.S. (Table 2.5). Most of the fatalities have been attributed to careless handling or storage practices and many of the fatalities have involved accidental ingestion by children (Keith, 1987).

Barrons (1987) observed that the number of illnesses from overexposure to pesticides exceeds the number of deaths, although there are no national statistics on illnesses. It was noted that illnesses and fatalities related to pesticide use are decreasing in the U.S. for reasons which include (Barrons, 1987):

1. the elimination of certain products and practices that were hazardous,
2. the strengthening of precautionary statements on pesticide labels,
3. new rules specifying when it is safe for farm workers to reenter a treated field, orchard, or vineyard,
4. the grouping of pesticides into restricted and nonrestricted categories, with the former available only to licensed farmers and operators, and
5. improved understanding by farm managers of the need for caution and worker education, and a parallel improved awareness on the part of home and commercial applications.

Although the number of illnesses and fatalities related to pesticide use is declining, farms still have the dubious recognition as the deadliest workplace in

Table 2.5. Number of Lethal Pesticide-Related Accidents in the U.S. in Different Years

Time Period	Lethal Pesticide-Related Accidents Per Year
1956	152
1961	111
1968-1970	55
1971-1973	38
1974-1976	32
1977-1979	31
1980-1982	28
1983-1984	27

Source: Keith C. Barrons, "How Risky are Pesticides." Science of Food and Agriculture Journal 5(1) (1987): 22.

America. Wilkerson (1988) wrote that farming has surpassed mining and construction in recent years as the nation's deadliest occupation and is claiming the lives of hundreds of children and leaving thousands disabled. It was noted that about 1,600 adults were killed in 1987 through tractor rollovers, farm machinery gears, and a host of other accidents. In addition, 160,000 were disabled, and it has been observed that 300 children under the age of 16 died in farm-related mishaps while 23,000 children were injured using or playing near farm equipment (Wilkerson, 1988).

In 1987, "the farm death rate was 49 deaths per 100,000 workers as against 38 deaths per 100,000 in mining, 35 per 100,000 in construction and 6 per 100,000 in manufacturing." Compared to 1978, "there were 52 deaths per 100,000 farm workers as against 56 deaths per 100,000 workers in mining and 48 deaths per 100,000 in construction" (Wilkerson, 1988). It is not clear how many of the farm deaths, accidents and illnesses, is attributable directly to pesticides and pesticide use.

Besides human injuries, illnesses, and deaths resulting from pesticide use and misuse, pesticide injury on crops is also a concern. Minimizing and eradicating such injuries on crops improve yields and profits for farmers. Stoller et al. (1973) observed a reduction in seed yield suspected to be due to injury from excessive herbicide rates or competition from uncontrolled weeds. There is also the concern of possible nutritional alterations induced in food by pesticides (Stoller, 1973). Penner and Meggitt (1970) found changes in fatty acid composition, yield, and plant injury resulting from treatment involving 13 herbicides in two soybean cultivars.

Factors that Determine the Movement of Pesticides in the Environment

.How effective applied pesticides and herbicides especially are depends on several factors related to the transport or movement of herbicides. Similarly, the loss of herbicides through surface runoff, vaporization and leaching is dependent on a number of factors. Consequently, it is presumed that the magnitude of the negative impacts of pesticide use and misuse, such as ground and surface water pollution is intricately tied to the factors that influence the movement of herbicides.

Bailey et al. (1974) noted that, of the many factors that influence the extent of pesticide runoff from agricultural land, several may be controlled to minimize pollution. Furthermore, Bailey et al. (1974) concluded that if the effects and interrelations of pesticide type and formulation, soil properties, climatic conditions, watershed characteristics, and agricultural practices were clearly known, usage guidelines could be developed that would aid in preventing runoff and subsequent pollution.

Hartwig and Hall (1980) indicated that the amount of herbicide loss depends on soil, climatic, and herbicide factors. The soil factors include texture, porosity, pH, organic matter, soil water content, and slope. The climatic factors are proximity of the rainfall in relation to herbicide application and to other rainfalls, intensity, and duration of rainfall, and total rainfall amounts. Included in herbicide factors is herbicide formulation and whether the herbicide is applied directly to plant foliage, the soil surface, or is incorporated into the soil (Hartwig and Hall, 1980).

Glotfelty et al. (1984) showed that the total amount of herbicide reaching the Wye River estuary dependend upon the quantity applied and the timing of the runoff with respect to application dates. It was found that the most important rainfall events are those that occur within two weeks of application. In addition, the formulation of the herbicide, especially wettable powders confirmed to be critical since they are susceptible to runoff losses.

Willis and Hamilton (1973) wrote that

> the magnitude of pesticide loss in runoff depends on a number of variables including the chemical properties of the compounds, rate of application, topography, vegetative cover, runoff volume, and climatic factors such as rainfall intensity.

Triplett et al. (1978) found that the quantity of herbicides transported increased with the amount of runoff and was inversely related to the length of time between application and runoff event.

Utilizing an agro-ecosystem approach billed as holistic since "an isolated study of the parts will not permit the comprehensive understanding of the complete system because the separate parts are linked interactively," Bailey et al. (1985) stated that the response of an agro-watershed to pesticides or other chemical pollutants is "determined by the combination of physico-chemical characteristics of the soils and chemicals themselves, topography, vegetation, geology, and well and drainage networks." Inputs into the systems were categorized as deterministic and stochastic with examples as timing of pesticide application (deterministic) and occurrence of rainfall (stochastic). Outputs originating from the agro-ecosystem, "include food and fiber plus sediment, pesticides, nutrients, heavy metals and easily oxidized organics, plus residues on the land surface, in runoff and leachate and in the air" (Bailey et al., 1985).

As illustrated by Bailey et al. (1985) and in Figure 2.2, "the watershed level response can be multimedia in dimension (land to water, land to atmosphere, and atmosphere to land)."

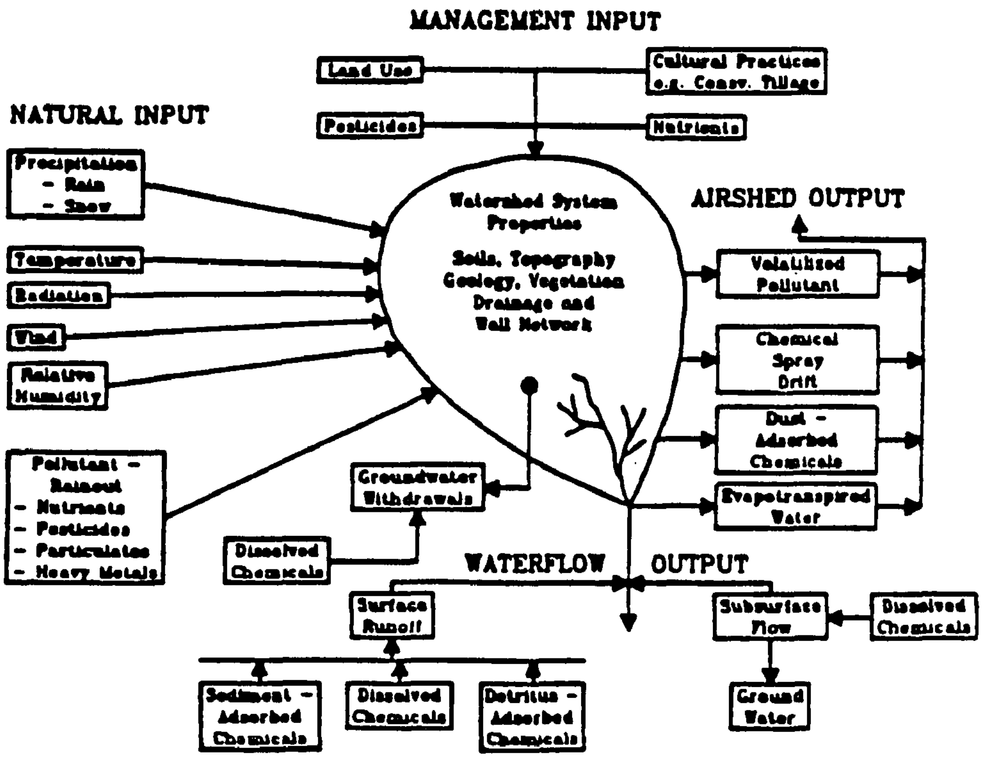


Figure 2.2 Factors Influencing the Behavior and Export of Agricultural Chemicals From an Agricultural Watershed.

Source: Bailey, Mulkey, and Swank. Environmental Implications of Conservation Tillage: A Systems Approach, 1985.

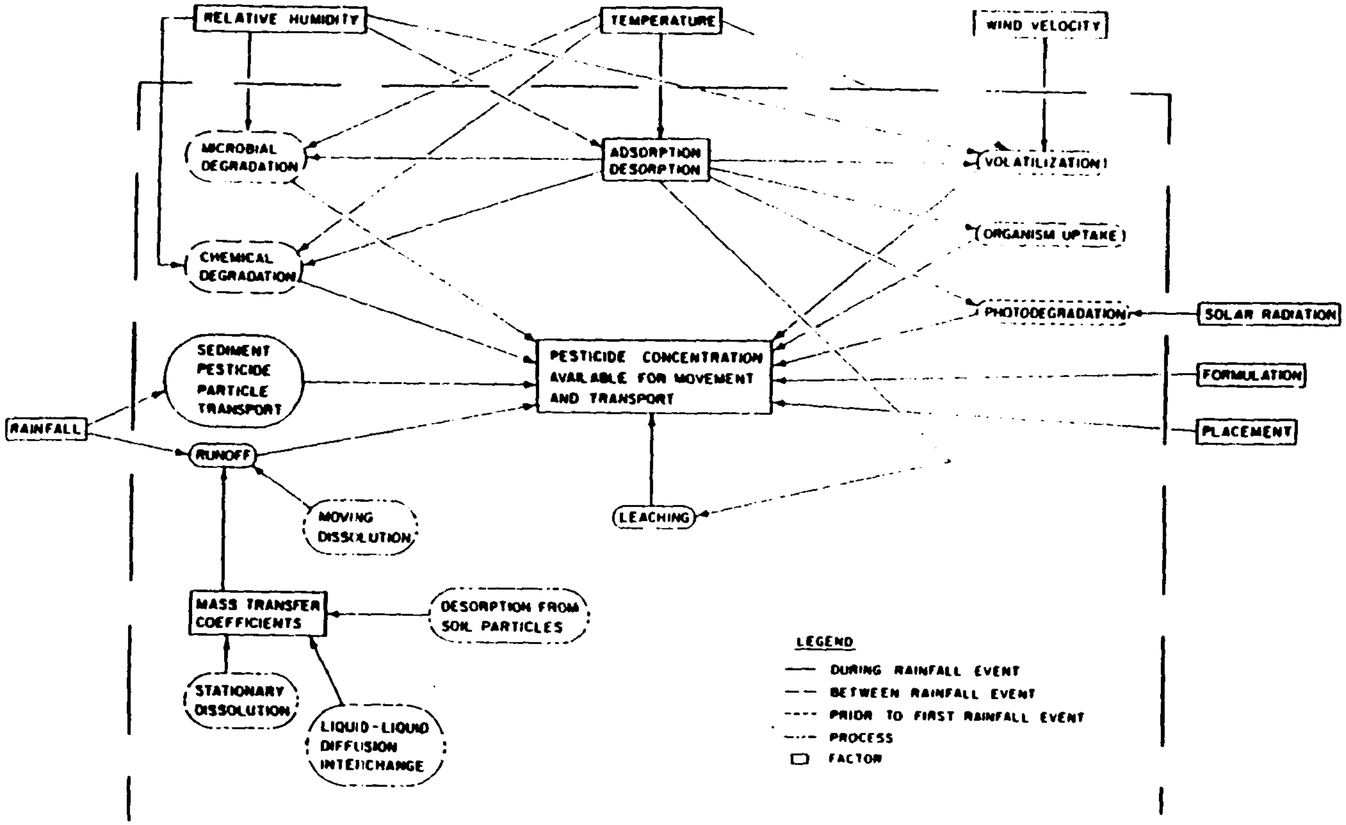


Figure 2.3 Processes and Factors which Determine the Concentration of Pesticide Available for Runoff from Agricultural Land. Climatic Factors lying Outside of the Dashed Lines are Exogenous with Respect to the Soil-Pesticide System.
Source: Bailey, et al., 1974.

Bailey et al. (1985) also noted some chemical characteristics of pesticides that influence transport from the soil. They include ionic state (cationic, anionic, basic, or acidic), water solubility, vapor pressure, partition coefficient, hydrophobic/hydrophilic character and chemical and biological reactivity.

Factors determining the movement or transport of pesticides are complex in nature. This complexity is further illustrated in Figures 2.2 and 2.3 by Bailey et al. (1974).

Pesticides are also lost through leaching or downward movement into the soil. Bailey et al. (1985) acknowledged that "pesticides move into the soil as a result of water infiltration and vertically through the soil during conditions of saturated flow." Furthermore, it was acknowledged that "downward movement starts before runoff since runoff does not begin until rainfall intensity exceeds the infiltration rate or the water volume exceeds the total storage capacity of the system."

Important factors seen to influence leaching include,

> adsorption-desorption, chemical reactions, pesticide application rate, water solubility of the pesticide, and physical properties of the soil, particularly those that determine average pore water velocity, water flux (flow rate), and total amount of water (Bailey et al., 1985).

Of all the factors, adsorption was noted as the most important factor of all. A further discussion of the key physical and chemical characteristics of pesticide leachers and the key soil factors affecting pesticide transport to groundwater is included in the appendix. Also included in the appendix are herbicide formulations, choice of formulations, and herbicide classification and mode of action.

No-Till (NT) Compared to Conventional Tillage (CT)

Definitions

No-till planting, also known as zero-tillage, is a form of conservation tillage in which the soil is left undisturbed until planting. Equipment merely opens slots in the soil to place seeds or fertilizer during planting operations (Conservation Tillage Information Center, 1985).

Conservation tillage has been defined as "any tillage sequence that reduces loss of soil or water relative to conventional tillage; often a form of non-inversion tillage that retains protective amounts of residue mulch on the surface" (Resource Conservation Glossary, 1982). The term "conservation tillage" is used when 30 percent of the soil surface is covered by plant residues from previous crops after planting (Conservation Tillage Information Center, 1985).

Van Es and Notier (1988) characterized no-till farming as a farming method where weed control is accomplished entirely by the use of herbicides and involving noninversion of the soil as well as the maintenance of residues on at least 60 percent of the surface throughout the year. Conventional tillage also known as clean tillage was defined as involving the inversion of the filled layer and incorporating residue to prepare a clean seedbed.

Christensen and Magleby (1983) described conventional tillage as where 100 percent of the topsoil is mixed and inverted by plowing, power tiller, or multiple diskings.

History and Trends in No-Till

Three events are involved in the initial history of no-till. Van Es and Notier (1988) noted that the first application of no-till farming was in pasture renovation resulting from tests conducted in Connecticut and New Jersey in 1945 and 1949, respectively. The tests were known to have originated out of a research begun in Wisconsin in the 1920's. From the 1949 research, it was discovered that "chemicals, even without discing, achieved good results for forages."

In terms of effectiveness, it was noted that the first effective demonstrations of the possibility of using no-till for row crops were conducted in the early 1950's in Michigan by Barrons (Van Es and Notier, 1988).

The third event with regard to the history of no-till is in terms of farm experiences. The best known experience dates back to 1950's by a group of farmers in Christian County, Kentucky (Van Es and Notier, 1988). The farmers were said to have begun no-till in an emergency when a wet spring made cultivation impossible and causing weeds to be chemically controlled. King (1983) also reported that no-till began in Kentucky.

Trends

No-till was in its preliminary stages in the 1960s, but has grown remarkable since in terms of acreages in the U.S. No-till acreage in 1982 was 10.5 million acres compared to 3.3 million acres (or an increase of 313 percent) in 1972. In 1981, no-till acreages increased 22.1 percent from 1980 and from 1981 to 1982, there was an additional 13.4 percent increase (No-till Farmer, Inc., 1982).

The 1988 Michigan No-Till Survey showed a 13 percent increase in no-till corn from 250,000 acres in 1987 to 282,000 acres in 1988. No-till soybeans showed an even larger growth as acres of no-till soybeans increased 40 percent from 49,000 acres to 69,000 acres from 1987 to 1988.

Factors Attributed to the Rise in Interest in No-Till

Phillips (1984) noted four factors which contributed to the increased interest in no-till. The factors are:

1. the development of plant growth regulators, especially the nonselective contact weed control material which provided the ability to eliminate or severely suppress existing vegetation,

2. population shifts to urban areas which depleted farm labor and resulted in capital investment in substitutes, such as pesticides, equipment, and other production items,

3. the introduction by farm equipment manufacturers of modified no-tillage planting equipment capable of placing seeds into uncultivated, unprepared soils, and

4. the fact that "farmers faced with normal and associated reduced yields by delayed planting were more receptive to practices that would save time in establishing crops such as was afforded by the adoption of no-tillage."

Characteristics of No-Till Farmers

Bultena and Holberg (1983) remarked in their study in Iowa determining factors affecting adoption of conservation tillage, that early adopters of innovations such as no-till often differ in their characteristics and other situations from person who adopt practices later or persons who never adopt new practices. Furthermore, Bultena and Holberg (1983) found that early adopters of conservations tillage were younger, "farmed larger units, had higher farm incomes, were more predisposed to risk-taking, had more potential for soil erosion on their cropland" as well as the perception that "others in their local communities generally favored conservation tillage."

Carlson and Dillman (1986) also noted in their study of early adopters and nonusers of no-till in the Pacific Northwest that "no-till users farmed more land, especially rented land; had higher incomes, had more education and were more likely to farm under a family corporation."

Explaining some of the differences between adopters and nonadopters of innovations, Bultena and Holberg noted that younger and better-educated people, for example, "usually are more knowledgeable about the newer practices, are more receptive to risk-taking, and have more incentive for adoption because of longer payoff period."

Advantages of No-Till

Moody et al. (1961) found that it is possible to grow corn in "a dead sod with no tillage." Furthermore, Moody (1961) indicated that:

> this new approach to growing corn affords excellent soil and water conservation in that the dead grass acts as a mulch to protect the soil surface, thereby reducing runoff and evaporation. In addition, the data suggests that tillage may have destroyed the favorable structure that grass crops usually promote.

Several studies since Moody et al. (1961), including King (1983), Mannering and Fenster (1983), Lee (1983), Moldenhauer (1985), Moldenhauer et al. (1983), Thomas (1985), Blevins et al. (1983), Rotz et al. (1985), Baker (1985), and Van Es (1988) and Stinner and House (1989) have discussed the advantages of no-till as well as the concerns or disadvantages. Some of the advantages of no-till include erosion control and savings in time, energy, and machinery costs. Glenn and Angle (1987) found that there was less runoff of water, atrazine and simazine from NT compared to CT.

Burnside (1985) listed some advantages of low-tillage cropping systems which includes no-till. They are:

1. Reduced soil erosion
2. Moisture conservation
3. Reduced energy and labor needs
4. Reduced equipment and production costs

5. Fewer destruction of fauna and

6. Increases in soil organic matter

Phillips (1984) noted that no-tillage techniques offer another advantage in that they are adaptable to most crops.

Acknowledging potential "sweeping generalizations with many exceptions to every rule," Gersmehl (1978) wrote that "no-till farming interposes a barrier of dead organic material between the soil and the atmosphere." Consequently, "raindrop impact is absorbed by the dead sod or the residues of previous crops. Wind is likewise blunted and unable to dislodge soil particles."

Gersmehl (1978) also wrote that

> no-till farming alters the water budget of the soil surface. The structure of the soil is improved, with less tendency to from a crust. Water can infiltrate more rapidly and the soil becomes more moist. Root growth is enhanced, except on already wet sites. The increase in infiltration leads to a reduction in overland runoff, accompanied by declines in soil erosion, fertilizer loss, and the rate of sedimentation and eutrophication downstream.

Furthermore, Gersmehl (1978) indicated that in no-till farming, fewer trips are required across a field and "less labor is needed for fieldwork, so field operations can be more timely. Less fuel is used, less horsepower is needed, and less capital is tied up in machinery."

The advantages of no-till not withstanding there are problems and concerns associated with it. Glenn and

Angle (1987) suggested that the decline in submerged aquatic vegetation (SAV) in the Chesapeake Bay and its tributaries may be attributed to an increase in no-till and herbicide use. A primary concern of no-till is the ecological impact, especially, on the groundwater as well as potential and unknown effects of direct human exposure and contact. The concern exists about groundwater contamination because infiltration increases with reduced tillage (Brink, 1977).

Several studies, including Phillips et al. (1980), Crosson (1981), Crosson et al. (1986), Baker (1985) Hayes (1982) indicated that more pesticides and herbicides are used in conservation tillage and no-till than in conventional tillage. Pimenthal (1984) suggested that since pesticide use is "sometimes doubled with no-till, the energy inputs would be greater than conventional tillage when pesticides are included in the energy budget." Phillips et al. (1980) noted that the use of more corn seeds (about 13%) in no-till than in conventional till to offset poor germination is energy input often excluded in the energy budget. The addition of such energy costs consequently would make for higher energy inputs in no-till than in conventional till.

Other concerns were indicated by Phillips (1984). They include:

1. a higher level of management or new technology that would be required by growers,

2. fertilizer usage and timing which may vary from that of conventional tillage,

3. producers who must learn planting techniques that will provide sound planting principles, and

4. the aesthetics associated with no-till as many farmers find it difficult to accept the ragged appearance of no-till compared to the clean soil surface associated with conventional till.

Gersmehl (1978) acknowledged that although labor time decreases, in no-till, "management complexity increases"and reductions in machinery and fuel costs are offset by higher pesticide expenses. Yields are often equal to those from conventionally plowed fields and in some case are significantly higher, but the potential for spectacular crop failure is also greater, because a reduction in the number of field operations also restricts the opportunity to correct errors.

Wauchope (1987) answered categorically "yes," especially for herbicides in a self-posed question on whether conservation tillage increases pesticide use. Estimated increases for herbicide use was observed to range from 15 to 60 percent.

Theory of Self-Interest

Farmers have been known historically to maximize profits by maximizing yields. In recent decades, marginal lands were put into production with extra inputs of fertilizers and pesticides to achieve maximum yield (Brink, 1977). This behavior, which is not only characteristics of farmers, is common to people in general. It is associated with an influential theory of society-nature relationships in which people respond to their physical environment, and thus, also to each other, on the basis of their short-term economic self-interest (Rickson and Stabler, 1985; Gordon, 1954; and Hardin, 1968).

Rickson and Stabler (1985) indicted that the assumption is that, "individuals using the same natural resource will attempt to maximize their benefits or returns from using it, and to share the costs of its inevitable destruction with others. The result is a gradual, if unintended, degradation of commonly owned resources, such as land, air, or water, and a 'tragedy of the commons.'"

In summary, Chapter II covered several items in the literature including the historical development of herbicides and pesticides, trends in the use of pesticides, economic importance of pesticides, environmental and health implications of pesticide use and misuse, herbicide formulation, comparison between no-till and conventional till and the advantages and disadvantages of no-till.

CHAPTER III

DESIGN OF THE STUDY

This chapter includes a description of the population, the selection of the population, the instrument utilized in data collection, the steps followed in collecting the data, and the limitations of the study.

The Population and Its Selection

The population for this study was comprised of 376 no-till corn farmers in nine counties in the southern peninsula of Michigan. The counties are Berrien, Cass, Clinton, Eaton, Hillsdale, Ionia, Ingham, Isabella, and Lenawee (Figure 1.2). The population was provided by District Conservationists in the nine counties with each providing a list of no-till corn growers from each of the counties. Each of the counties had 10,000 or more acres of no-till corn, the largest no-till corn acreages in Michigan in 1986. No-till corn was chosen because it is the most widely grown grain crop in Michigan. Consequently, a greater amount of herbicides was expected to be applied to no-till corn than to any other grain crop such as wheat or soybean. Fleming (1987) noted that more than half of the herbicides applied to field crops are applied to corn and that corn accounts for almost half of all the fertilizer used in the U.S. Corn was also chosen because it is a popular crop universally.

The list of the farmers were solicited from the District Conservationists through phone calls, letters, and personal contacts by the researcher.

Instrumentation

A survey questionnaire was developed to gather information that responds to the research questions (see Appendix A). Since surveys were conducted in 1988 and 1989, two similar questionnaires were used, although there was one additional question in the 1989 questionnaire added to retrieve information on the size of no-till corn acreages planted in 1987 (see Appendix B).

The survey/questionnaire was developed with the assistance of the researchers committee members, particularly Dr. J. Kells and Dr. E. Dersch, as well as Dr. Frank Fear, Chairperson of the Department of Resource Development, and Dwight Quisenberry, formerly the State Conservation Agronomist with the U.S. Soil Conservation Service. A mail questionnaire was used because of the wide geographical distribution of the population and because it was comparatively more time and cost efficient than telephone or face-to-face surveys.

Mr. Quisenberry and two other District Conservationists were involved in a pilot study. They critiqued the questionnaire from the viewpoint of farmers since they have had many years of experience working with farmers. Another expert with the U.S. Soil Conservation Service who is also a farmer was asked for his feedback on the survey.

The questionnaire was divided into four sections. The sections asked questions relating to practice, as well as institutional, environmental, and demographic questions.

Administration and Return of Questionnaires

A cover letter was attached to the questionnaires before they were mailed. The cover letters were signed by the researcher and Dwight Quisenberry, former State Conservation Agronomist. Mr. D. Quisenberry's signature was to assure the District Conservationists and the farmers of the intent and the need for the study, as well as to add credibility to the study.

This study involved two batches of the same survey questionnaires. On April 20, 1988, questionnaires were mailed to 200 randomly selected no-till corn farmers in the nine counties under study. Thirty-nine, or 19 percent, responded prior to the follow-up letter which was sent on May 23, 1988. After the follow up letter, a total of 81 responded.

Although 81 farmers responded, only 53 were valid since 28 farmers indicated that they were not no-till farmers. Two surveys were returned because they were undelivered due to change of address.

In an effort to improve on the validity of the study, another set of the same questionnaires was mailed to the rest of the farmers (176). The questionnaires were mailed on February 14, 1989. A follow-up letter was mailed to each of the farmers in the second batch on March 14, 1989. The questionnaires were sent this time in winter prior to the farming season with the hope that a higher number of responses would be received since the farmers were not expected to be as busy as in the early farming season in Spring (April-May). The survey was terminated on April 14, 1989, a week after no other response was received.

Forty-four invalid responses were received out of a total of 83 responses. The invalid responses consisted of eight returned envelopes due to change of address, 28 responses that do not plant no-till corn, and eight responses which were not utilized because of missing data, particularly acreage of no-till and herbicides applied.

The valid responses from the 1988 survey were added to the 1989 valid responses for a total of 92 or 30.2% of the population excluding the returned, but invalid, responses (Table 3.1).

Table 3.1. Number of Mailed Questionnaires and Response Rates

	First Mailing (4-20-88)	Second Mailing (2-14-89)
Total Number Sent	200	176
Total Number of Responses	81	83
Total Number of Valid Responses	53	39
Total of Invalid Responses	28	44
Total of Valid Responses	92	
Total Percentage = 30.2%		

Data Analysis

Statistical Package for the Social Sciences (SPSSX) was used to analyze the data for this study. Simple descriptive statistics ranging from frequencies, percentages, to means, and standard deviation were used. The t-test, analysis of variance (ANOVA) and Pearson's

Moment Correlation coefficient were utilized in analyzing some of the research questions.

The primary purpose of the study is to determine whether no-till corn farmers in nine Michigan counties are applying herbicides according to recommended rates on container labels.

The primary dependent variable in the study is herbicide rates expressed in active ingredients. A major advantage of converting the formulation's active ingredient is that the result of the conversion is expressed in pounds per active ingredient. Conversion to active ingredients was based on the amount of herbicides as well as the concentration and the commercial formulation. For example, atrazine and cynazine (bladex) were applied in various quantities, but in three formulations primarily 80% wettable powder (80W), 90% water dispersible granule (WDG) or dry flowable (DF) and as 4 lb/gal water dispersible liquid suspension (4L).

Three examples will be used to illustrate the conversion of applied herbicides to active ingredients. atrazine which was applied as wettable powder (80W), water dispersible granule (90 WDG) and as liquid (4L) is used for the illustration. Assuming that three farmers applied 2.5 pounds of 80W, 2.0 lbs of 90 WDG, and 1.5 quarts of atrazine, respectively, the conversion to active ingredients is as follows:

1. 2.5 x 0.8 lb a.i. = 2.016 a.i.

2. 2.0 x 0.9 lb a.i. = 1.816 a.i.

3. 1.5/4.0 gal 4L=0.37 x 4 lb a.i.=1.48 lb a.i.

The following is a presentation of each of the research questions and a brief description of the statistical analysis used to address each question.

<u>Research Question 1</u>. To what extent do herbicides applied by no-till corn farmers (on their no-till corn acreage) in nine Michigan Counties conform with the recommended rates on container labels?

Respondents were asked to indicate the type of herbicides, their formulations and rates (in pounds, quarts, kilograms, or liters) they applied in preemergence and post-emergence no-till corn.

Based on the responses, descriptive statistics including means, standard deviation, ranges, and percentages were used to determine if the respondents applied herbicides according to recommended rates.

<u>Research Question 2</u>. To what extent do herbicide rates applied by the same no-till corn farmers on their no-till corn acreage conform with herbicide rates they apply on conventional-till corn acreage?

Like Research Question 1, the respondents were asked to indicate the herbicides, formulations, and rates they applied in preplant, preemergence, and postemergence conventional corn acreages.

Based on the responses, the means, standard deviation, ranges, and percentages based on conventional acreages was compared to the means, standard deviation, ranges, and percentages based on no-till corn acreages. Furthermore, the t-test was used to determine whether or not there exists significant differences in the rates of herbicides applied by the farmers in no-till and conventional till acreages.

Research Question 3. To what extent does the level of education influence the rate of herbicides applied by the farmers?

The respondents were asked to indicate their highest level of education ranging from "less than high school" to undergraduate and graduate degrees.

The t-test was then used to determine the significance of the difference in rates of herbicides applied between those respondents with high school education and less, and those with above high school education. In this study, those with high school education and less are designated as the less-educated, whereas those with above high school education are designated as the more educated respondents.

Research Question 4. To what extent does ownership or rental of farmland influence the rate of herbicides applied by the farmers?

The respondents were asked to indicate whether they own or rent their no-till corn acres or whether "both" apply given the choices of (1) own, (2) rent, and (3) both.

Based on their responses, the ANOVA was used to determine whether or not significant differences exist in the rates of herbicides applied by those farmers who either own or rent their no-till corn farm and those who both own and rent.

Research Question 5: To what extent does farming status (full-time or part-time) influence the rate of herbicides applied in no-till corn?

The respondents were asked whether they are full- or part-time farmers. The t-test was used to determine whether or not significant differences exist in the rate of herbicides applied between full-time and part-time farmers.

Research Question 6: To what extent do farmers' environmental awareness influence the rate of herbicides they applied?

Respondents were asked whether or not they think agricultural practice is a significant source of environmental pollution in their county relative to other sources of pollution such as industries.

Based on the responses, the t-test was used to determine whether or not there exists significant differences in the rate of herbicides applied by those farmers who acknowledged that agricultural practices are significant sources of environmental pollution relative to other sources of pollution and those farmers who disagree that agricultural practices are significant sources of environmental pollution relative to other sources of pollution such as industries.

Research Question 7: To what extent does income influence the rate of herbicides applied by the farmers?

The respondents were asked to indicate their after-taxes annual farm income from a list ranging from "less than $10,000" to "above $60,000." Three levels of income, lower, middle, and higher income were determined. In this study, lower income farmers are those with incomes of less than $15,000. Middle income farmers are those with incomes ranging from $15,000 to $25,000, and higher income farmers are those with incomes above $25,000. Based on the responses, Analysis of Variance (ANOVA) was used to determine if significant differences exist in the rate of herbicides applied between lower, middle, and higher income farmers.

<u>Research Question 8</u>: To what extent does the size of the farm influence the rate of herbicides applied?

The respondents were asked to indicate how many acres of corn they planted in no-till and conventional till. The Pearson's Moment Correlation Coefficient was subsequently used to determine if there was a statistically significant relationship between the size of the farm and the rates of herbicides applied.

<u>Research Question 9</u>: To what extent do years in continuous no-till corn influence the rate of herbicides applied?

Respondents were asked to indicate how long (years) they have planted continuous no-till corn. From their response, the Pearson's Moment Correlation Coefficient was used to determine if there is a statistically significant relationship between the number of years a farmer has cultivated continuous no-till corn and the rates of herbicides applied by the farmer.

One drawback of utilizing surveys to gather information is the potential for respondents to give desirable and inaccurate responses. For example, no farmer is expected to admit that he or she applied a higher rate of herbicide than recommended, especially if such overapplication is potentially against the law. Chances, therefore, are that some of the responses obtained in this study might have been socially or environmentally desirable answers to the questions in the mailed questionnaire. However, the fact that mailed questionnaires were used rather than face-to-face interviews might have minimized such a problem, especially since the anonymity of respondents was assured.

It is noteworthy that two of the respondents after being contacted by phone to clarify a response they put down on their completed questionnaire requested that the researcher "hold on for a moment" while they checked their records to confirm the rates they had indicated in the questionnaire. The rates they indicated after consulting their records were the same as what they had written down in the questionnaire, thereby confirming the accuracy of their initial answer on the questionnaire.

The exchange over the phone with the two farmers was an indication that at least a few of the farmers do maintain good records. Such minimizes the fear of desirable answers.

In conclusion, Chapter III discussed the design of the study including the population and its selection, instrumentation, administration and return of questionnaires and a brief description of the statistical analysis used to address each of the nine research questions.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

Introduction

This study attempted to determine whether or not no-till corn farmers in nine Michigan counties apply herbicides according to recommended rates on container labels. This study also examined whether or not the same no-till corn farmers apply the same rates of herbicide on no-till and conventional till acreages.

From a list of 376 farmers representing nine Michigan counties, 92 participated in this study. The nine Michigan counties included Berrien, Cass, Clinton, Eaton, Hillsdale, Ingham, Ionia, Isabella, and Lenawee.

General Characteristics and Observations

The 92 no-till corn farms used in this study ranged in size from 1 to 2,700 acres of corn. The average no-till corn acreage was 151 acres. Of the 92 respondents, 65 (or 70.7%) also planted conventional corn. The range in size of the conventional corn acreages was from 13 to 1,000 acres, while the average size of conventional corn acreage was 154 acres.

Table 4.1 shows the range of corn acreage, number of responses, and percentage of responses in no-till and conventional tillage.

Table 4.1. Range of Acreages and Percentages of No-Till and Conventional Till Acreages.

Acreage	No-Till		Conventional Till	
	No. of Respondents	Percentage	No. of Respondents	Percentage
1-199	73	79.3	47	72.3
200-399	12	13.0	13	20.0
400-599	5	5.4	1	1.5
> 600	2	2.2	4	6.1
Total	92	100.0	65	100.0

Of the total 92 farmers, 73 (or 79%) had less than 200 acres of no-till corn, while 47 (or 72%) had less than 200 acres of conventional corn acreages.

The number of years the respondents have raised no-till corn ranged from 0 to 22 years. Table 4.2 presents the number and percentage of years the respondents have raised no-till corn.

Table 4.2. Number of Years in No-Till Corn and Percentage of Responses

Years in No-Till	Number of Responses	Percentage
5 or less	49	53.2
6-11	31	33.6
12-17	10	11.0
> 17	2	2.2
TOTAL	92	100.0

Of the 92 respondents, 49 (or 53%) have raised no-till corn for five years or less while 80 (or 86%) have raised no-till corn for eleven years or less.

The respondents were asked to indicate the most recent year they tested the soil in their no-till corn acreages. Table 4.3 shows the number and percentage of the respondents according to the year they tested the soil in their no-till corn acreages.

From Table 4.3, 82 (or 89%) of the respondents tested their no-till soil between 1985 and 1988.

Respondents were asked to indicate the soil texture that best describes the texture of their no-till corn acres. The five most common soil textures identified by the respondents are clay, clay loam, sandy

Table 4.3. Most Recent Year the Respondents Tested the Soil in Their No-Till Corn Acreages

Year	Number of Responses	Percentage
Prior to 1984	3	3.3
1984	6	6.5
1985	13	14.3
1986	20	22.0
1987	35	38.5
1988	14	15.4
TOTAL	92	100.0

loam, and loamy sand. Table 4.4 shows the number of responses by soil texture. As shown in Tables 4.4, clay loam, sandy loam, and loam are the dominant textures.

Slightly less than one-half of the respondents own their no-till corn acreages. That is, 43 (or 46%) own their no-till corn acreages while only 14 (or 15%) rent. Of the respondents, 35 (or 38%) indicated that they both own and rent.

The respondents were asked how many times they call or visit with their Cooperative Extension or Soil Conservation personnel in an average month of thirty

Table 4.4. Most Common Soil Textures Identified by Respondents and Their Percentages.

Soil Texture	Number of Responses	Percentage
Clay	5	5.4
Clay loam	31	33.7
Sandy loam	25	27.2
Loam	19	20.7
Loamy sand	6	6.5
Others	6	6.5

days. The options given for the answers ranged from less than two times in the month to more than ten times.

Table 4.5 shows the number of visits and telephone calls to Cooperative Extension and Soil Conservation personnel. As shown in Table 4.5, 78 (or 84.8%) of the respondents visit with their Cooperative Extension or Soil Conservation personnel twice or less in an average month, and 74 (or 80%) have two or fewer contacts by telephone with their Cooperative Extension or Soil Conservation personnel.

On a rating scale ranging from "N" (not important) to "V" (very important), the respondents were asked to rate the importance of each of the ten various

Table 4.5. Number of Visits and Telephone Calls to Cooperative Extension or Soil Conservation Personnel per month.

	Personal Visits		Phone Calls	
No. of Visits and Calls	No. of Respondents	%	No. of Respondents	%
< 2 times	78	84.8	74	80.4
2-4 times	11	12.0	12	13.1
5-7 times	3	3.2	1	1.1
8-10 times	0	0	4	4.3
> 10 times	0	0	1	1.1

sources of information for the herbicides they applied. Table 4.6 shows sources of information for the herbicides the farmers applied and the number of respondents indicating "Very Important" for each source. The number of respondents is based on the 92 responses from the survey.

From Table 4.6, it is indicated that the top six sources of information for the respondents are container labels, chemical and fertilizer salespeople, Soil Conservation Service, Cooperative Extension Service, other farmers, friends, relatives or neighbors, and Soil Conservation District Directors.

Table 4.6. Source of Information for Herbicide Application and Number of Respondents Indicating "Very Important" for each source.

Source of Information	Respondents Indicating "Very Important" No. of Respondents	Percent
Container Labels	61	66.3
Chemical and Fertilizer Salespeople	38	41.3
Soil Conservation Service	34	37.0
Cooperative Extension Service	29	31.5
Farmers, friends, relatives or neighbors	19	20.6
Soil Conservation District Directors	18	19.6
Farm magazines and newspaper	7	7.6
Equipment Company representative	3	3.3
Radio or Television Programs	2	2.2
Local newspapers	1	1.1

*Number of respondents and percentages based on 92 responses indicating "Very Important" for each source of information.

It is worth exploring why container labels and chemical and fertilizer salespeople rank as the highest source of information as compared with Soil Conservation Service (SCS) and Cooperative Extension Service (CES). This researcher contends that proximity to the chemical (herbicide) sales depot and the aggressiveness of the chemical salespeople could have been important reasons. The researcher, however, contends that the most important reason possibly is that while on location at a chemical (herbicide) sale depot, the farmer is able to purchase the herbicides he or she needs, and at the same time, is able to obtain (or clarify some) information regarding herbicide application from the chemical salespeople. This is quite unlike SCS and CES officials who can only provide information regarding herbicide information but do not sell the herbicides. Thus, the farmer could "kill two birds with one stone" while on location at a herbicide sales depot. In addition, the farmer may also contact chemical (herbicide) salespeople over the phone if he or she chooses to do so.

A smaller percentage of respondents rated other sources as "very important." These other sources are farm magazines and newspaper, equipment company representative, radio and television programs, and local newspapers. For example, only 2% and 1% of the respondents, respectively, perceived radio or television programs and local newspapers as very important sources of information for herbicide application. The result suggests that fiscal resources spent on media (television, radio, and newspapers) for advertisement by chemical companies should be redirected elsewhere.

Although container labels provide the primary single source of information for herbicide application, the responses obtained indicate that a combination of federal and state supported services and agents, namely Soil Conservation Service, Cooperative Extension Service, and Soil Conservation District Directors is a larger source of information for herbicide application than container labels. The results suggests that the government supported services are being widely utilized as sources of information for herbicide application. However, such information services are not being fully utilized.

The respondents were asked if they think more herbicides are applied to no-till than to conventional till acres. Of the 92 respondents 54 (or 58.7%) believe that more herbicides are applied in no-till than in conventional till. When asked if they apply the same amount of herbicides to the same acreages each year, 49 (or 53%) indicated they apply the same amount of herbicides to the same acreages every year.

The respondents were asked to rate on a scale ranging from "Very Important" to "Not Important," the reasons for the amount of herbicides they applied in their no-till corn. Each of the reasons had options spanning from the most important to unimportant.

Table 4.7 shows the reasons for the amount of herbicides applied by the farmers, as well as the number of respondents and the percentage that indicated "very important" for each reason. As shown in Table 4.7, the three most important reasons why the respondents applied the amount of herbicides they applied in their no-till corn are: the type of weed, desire to increase farm profitability, and the desire to increase crop production.

The respondents were asked to indicate factors that would cause them to apply less herbicides than they applied in the previous year. Their response was based in an order of importance ranging from "Very Important" to "Not Important" for each selected reason.

Table 4.8 shows factors that would cause a reduction in the amount of herbicides applied in the current year compared to the previous year and the number and percentage of the 92 respondents that indicated "Very Important" for each factor or reason. As shown in Table 4.8, the primary reasons why the respondents would use less herbicides than in the previous year are:

Table 4.7. Reasons for the Amount of Herbicides Applied Based on the Number of Repondents for each Reason

Reason for Amount Applied	Respondents Indicating "Very Important"	
	No. of Respondents	Percent
Type of Weed	69	75.0
Desire to increase farm profitability	60	65.2
Desire to increase crop production	44	47.8
Personal farming habits	25	27.2
Advice from chemical and fertilizer sales agent	19	20.7
Advice from Local Soil Conservation District	16	17.4
Advice from Local Cooperative Extension Agent	14	15.2

*Number of respondents and percentages based on 92 responses indicting "Very Important" for each reason.

Table 4.8. Factors that would cause a reduction of use of herbicides than in the previous year

Factors for Using Less Herbicide	Respondents Indicating "Very Important"	
	No. of Resondents	Percent
Concern for surface and groundwater contamination in farmer's locality	43	46.7
Personal concern about potential injury from herbicide application	31	33.7
Concern for a potential rule violation	29	31.5
Advice from a chemical salesperson	26	28.5
Higher cost of herbicides in the current year	9	9.8
Advice from a fellow farmer	6	6.5

*Number of respondents and percentage based on 92 responses indicating "Very Important" for each factor.

1. Concern for surface and groundwater contamination in their locality
2. Personal concern about potential injury from herbicide application
3. Concern for a potential rule violation

The farmers were asked whether or not they think agricultural practices are significant sources of environmental pollution relative to other sources of pollution such as industries. Table 4.9 shows the number

Table 4.9. Responses to Whether Agricultural Practices are Significant Sources of Environmental Pollution Relative to other Sources Such as Industries

Response	No. of Repondents	Percent
Yes	33	35.8
No	57	62.0
Non-Response	2	2.2
Total	92	100.0

of the responses to whether or not agricultural practices are significant sources of environmental pollution relative to other sources such as industries. It also shows that of the 92 respondents, 33 (or 35.8%) perceived that agricultural practices are significant sources of environmental pollution while 57 (or 62%) disagreed.

With regard to the level of education of the respondents, the data indicated that almost all the 92 respondents are high school graduates and more. Only one respondent had less than a high school degree. Table 4.10 shows the number and percentage of the respondents' educational level.

Table 4.10. Level of Education of Respondents

Level	No. of Respondents	Percentage
Less than High School	1	1.1
High School Degree	47	51.1
2-Year Vocational Degree	12	13.0
Undergraduate Degree and Above	31	33.7
Nonresponse	1	1.1
Total	92	100.0%

The respondents were asked whether they are full-time farmers or part-time farmers. Full-time farmers were defined as those who derive all sources of their income from farming while part-time farmers were those who had other sources of income besides farming.

Table 4.11 shows respondents indicating they are full-time or part-time farmers.

Table 4.11. Number of Respondents Indicating Whether They Are Full-time Farmers or Part-time Farmers

Levels	No. of Respondents	Percentage
Yes*	73	79.3
No	18	19.6
Nonresponse	1	1.1

*Yes indicates full time; no indicates part time.

As shown in Table 4.11, 73 (or 79.3%) of the respondents indicated they are full-time farmers compared to 18 (or 19.6%) that indicated they are part-time farmers.

Of the 92 farmers, the data indicated that 27 (or 29%) were unwilling to answer income-related questions. Tables 4.12 shows the income levels of the respondents and the number and percentage of respondents in each income level.

As shown in Table 4.12, of the 65 respondents who indicated their after-taxes income, 20 (or 30.8%)

Table 4.12. Income Levels of Respondents and the Number and Percentage of Respondents in Each Income Level

Levels	No. of Respondents	Percentage
Below $15,000	10	15.4
$15,000-$24,999	10	15.4
$25,000-$34,999	21	32.3
$35,000-43,999	11	16.9
$44,000-49,999	5	7.7
$50,000-59,999	1	1.5
> $60,000	7	10.8
Non-Response	27	
Total	92	100.0%

indicated an income below $25,000. Thirty-seven (or 56.9%) showed income between $25,000 and $49,999, while 8 (or 13%) had income levels above $50,000.

All the herbicides applied in no-till and conventional till were tabulated. Only the most frequently applied herbicides used by at least 19 farmers were selected for further analysis in this study. Table 4.13 shows the frequency of usage of herbicides and by type of tillage and time of application.

Table 4.13 shows the most frequently applied herbicides and the number of respondents applying the herbicides in no-till and conventional till. The most frequently applied herbicides were atrazine, cyanazine, metolachlor, paraquat, glyphosate, and alachlor. Pre-emergence atrazine was the most commonly applied herbicide in both no-till and conventional till and it was the one herbicide for which 27%, or over one-fourth, of the farmers apparently applied beyond the recommended rate. Table 4.14 illustrates the common name and the trade name of the most frequently applied herbicides identified by the respondents.

The remaining part of this chapter is a presentation of the findings for each of the nine research questions. A brief description of the statistics used and the findings will be presented.

Research Question 1

Research Question 1. To what extent do herbicides applied by no-till corn farmers in nine Michigan Counties conform with the recommended rates on container labels?

Table 4.15 shows the mean (in lbs/acre) and the standard deviation of the applied herbicides and the range of recommended rates in active ingredients for the four herbicides applied in no-till and conventional till.

Table 4.13. Most Frequently Applied Herbicides and the Number of Respondents Applying the Herbicides in No-till and Conventional Till Corn

Herbicide	No-Till		Conventional Till		
	Pre-emergence	Post-emergence	Preplant	Pre-emergence	Post-emergence
	No. of Respondents[a]				
Atrazine	63*	7	25*	39*	8
Cyanazine (Bladex)	20*	3	4	13	1
Metolachlor (Dual)	19*	1	4	12	1
Paraquat (Gramoxone Super)	20*	0	0	0	0
Glyphosate (Roundup)	25*	0	0	0	0
Alachlor (Lasso)	29*	2	9	18	2

*Indicates those selected for further analysis in this study.

[a]Based on 92 responses.

Table 4.14. Common and Trade Names of the Most Frequently Applied Herbicides Identified by the Respondents.

Common Name	Trade Name
Atrazine	("Several")
Cyanazine	Bladex
Metolachlor	Dual
Paraquat	Gramoxone Super (Gramoxone Extra)
Glyphosate	Roundup, Ranger
Alachlor	Lasso, Arena, Micro-Tech Lasso

Source: 1990 Weed Control Guide for Field Crops. Cooperative Extension Service, Michigan State University.

Table 4.15. Comparison Between Actual and Recommended Herbicide Rates and Comparison Between No-till and Conventional Till Applications

Herbicide	No-Till							Conventional Till						
	N	Actual Rates		Rec. Rate*	Percentage			N	Actual Rates		Rec. Rate*	Percentage		
		$\bar{X}^a$ (a.i.)	S.D.[a]	Active Ingredients[a]	Below	Within	Above		$\bar{X}^a$ (a.i.)	S.D.[a]	Active Ingredients[a]	Below	Within	Above
Atrazine	62	2.580	1.572	1.98 - 3.0	44	29	27	30	2.771	1.447	1.98 - 3.0	26.7	40.0	33.3
Cyanazine (Bladex)	22	2.656	1.129	1.20 - 5.4	4.5	95.5	--	13	2.576	1.428	1.20 - 5.4	23.1	76.9	--
Metolachlor	18	2.056	0.539	2.00 - 3.0	5.6	88.8	5.6	13	1.958	0.753	2.00 - 3.00	41.7	50.0	8.3
Alachlor (Lasso)	28	2.179	0.593	2.00 - 4.0	14.0	86.0	--	18	2.261	0.469	2.00 - 4.0	5.6	94.4	--

*Recommended rate in active ingredients (converted from volume recommended rates)

[a](lbs/acre)

a.i. = Active Ingredients

For each of the herbicides listed, the recommended rate, and the percentage of farmers who applied herbicides below, within, and above the recommended range was indicated. The range of recommended rates were based on Crop Protection Chemicals Reference (1988) which contains recommended rates of herbicides as stipulated on container labels by various herbicide manufacturers.

The range of recommended rates takes into consideration the formulation of the herbicide, the organic matter content of the soil, and the soil texture. The recommended range of active ingredients for each herbicide was derived by conversion from volume formulations and from the results, the percentage of farmers who applied herbicides below, within, and above the recommended rates were determined. The conversion to active ingredients was done for each respondent and for each soil type. Among the no-till corn farmers, Table 4.15 indicated that 44% of the farmers who applied atrazine applied rates below the recommended rates; 29% of them applied atrazine within the range of recommended rates, while 27% applied above the range of recommended rates.

Of the respondents who applied cyanazine in NT, 95.5% applied the herbicide within the recommended rates; 4.5% applied the herbicide below the range of recommended rates; while 88.8% of those who applied metolachlor did so within recommended rates, and 5.6% of the farmers applied metolachlor below recommended rates. Similarly, 5.6% of the farmers applied the herbicide above recommended rates.

Table 4.15 also shows that in no-till corn, 86.0% of the farmers applied alachlor within the recommended range, while 14.0% applied the herbicide below the recommended range. None of the alachlor was applied above the recommended range.

In preemergence conventional till, 26.7% of the farmers applied atrazine below the range of recommended rates. However, 40% of the farmers applied atrazine within recommended range, while 28% applied above the range of recommended rates.

Application of cyanazine was below and within recommended rates in conventional till. Of the farmers, 23.1% applied cyanazine below the recommended rates, while 76.9% of the respondents applied the herbicide within recommended rates.

Regarding alachlor, 94.4% of the farmers applied it within the range of recommended rates, while 5.6% applied alachlor below the range of recommended rates.

Research Question 2

Research Question 2. To what extent do herbicide rates applied by the same no-till corn farmers conform with herbicide rates they applied on conventional till corn acres?

As illustrated in Table 4.15, the mean, standard deviation, and the range of recommended rates were computed. For each of the herbicides also the percentage of farmers who applied herbicides below, within, and above recommended rates was compiled. As shown in Table 4.15, 26.7% of the farmers who applied atrazine in conventional till applied it below the range recommended rates for preemergence, while 40.0% and 33.0% of the farmers applied atrazine within and above the range of recommended rates respectively for preemergence conventional till.

Furthermore, the t-test was used to determine if there is a significant difference in the rates of herbicides applied to no-till versus conventionally-tilled acreages.

Table 4.16 shows the t-test result for the difference between herbicide application rates in no-till and conventional till. As indicated in Table 4.16, similar rates of atrazine, alachlor, cyanazine, and metolachlor were applied by the farmers in NT and CT corn acres. There were no statistically significant

Table 4.16. T-test Result for the Difference Between Herbicide Application Rates in No-Till and Conventional Tillage (using T-test comparisons).

Herbicide		N	Mean (lbs/ acre) (a.i.)	Std.	t-Value	P-Value
Atrazine	No-till	28	2.8211	1.585	0.16	0.872
	Conventional	28	2.7907	1.441		
Alachlor (Lasso)	No-till	16	2.2500	0.438	1.41	0.178
	Conventional	16	2.200	0.453		
Cyanazine (Bladex)	No-till	10	2.5840	1.284	-0.66	0.526
	Conventional	10	2.7340	1.397		
Metolachlor (Dual)	No-till	9	2.1111	0.782	0.00	0.000
	Conventional	9	2.1111	0.782		

a.i. = active ingredient

differences observed at 0.05 level for all the applied herbicides in NT and CT corn acres. This finding is contrary to the perception by 58.7% of the respondents who agreed that more herbicides are applied in no-till than in conventional till.

Research Question 3

Research Question 3. To what extent does the level of education influence the rate of herbicides applied by the farmers?

A t-test was used to determine the significance of the difference in the rate of herbicides applied between those farmers with a high school degree and less, and those with above high school education.

Tables 4.17 and 4.18 show the t-test result of active ingredients or rate of applied herbicides by level of education in no-till and conventional till.

As shown in Tables 4.17 and 4.18, no significant differences were found in either no-till or conventional till with regard to the rates of herbicides applied and the levels of education. Consequently, the results indicate that levels of education of the respondents did not influence the rates of herbicides they applied since the respondents applied similar rates of herbicides in no-till and in conventional till.

Table 4.17. T-test Result: Active Ingredient (herbicides) by Level of Education: No-Till only.

Herbicide	Demographic Variable	N	Levels	Mean (lbs/ acres) (a.i.)	Std.	T-Value	2-Tail Prob.
Atrazine	Education	39	High School/ Below	2.4592	1.524	-0.82	0.415
		23	>High School	2.8078	1.660		
Cyanazine	Education	9	High School/ Below	2.9778	1.218	1.09	0.294
		13	>High School	2.4338	1.054		
Metolachlor	Education	13	High School/ Below	1.9231	0.277	-1.17	0.302
		5	>High School	2.400	0.894		
Gramoxone Super	Education	14	High School/ Below	0.6696	0.358	-0.35	0.731
		6	>High School	0.7188	0.249		
Glyphosate	Education	11	High School/ Below	1.6364	0.452	-0.27	0.792
		12	>High School	1.6875	0.466		
Alachlor	Education	13	High School/ Below	2.1538	0.555	0.09	0.933
		15	>High School	2.1333	1.453		

a.i. = active ingredient

Table 4.18. T-Test Result: Active Ingredient (herbicides) by Level of Education: Conventional Only

Herbicide	Demographic Variable	N	Levels	Mean (lbs/ acres) (a.i.)	Std.	T-Value	2-Tail Prob.
Atrazine (PREM)	Education	17	High School/ Below	2.8376	1.742	0.30	0.765
		13	>High School	2.6848	1.002		
Cyanazine	Education	6	High School/ Below	2.1583	1.311	-0.99	0.345
		7	>High School	2.9343	1.525		
Metolachlor	Education	6	High School/ Below	1.8333	0.408	-0.56	0.596
		6	>High School	2.0833	1.021		
Alachlor (Lasso)	Education	6	High School/ Below	2.1167	0.449	0.94	0.367
		12	>High School	2.3333	0.481		

Research Question 4

Research Question 4. To what extent does ownership or rental of farmland influence the rate of herbicides applied by the farmers?

The three levels of ownership in the survey questionnaire are "own," "rent," and both." The respondents were asked if they own or rent their no-till corn acres or whether they both own and rent.

Analysis of Variance (ANOVA) was used to determine if significant differences exist in the herbicide rates applied by those farmers who strictly own their no-till corn acres and those who exclusively rent their no-till corn acres as well as those who own and rent their no-till corn acres.

Tables 4.19 and 4.20 show Analysis of Variance results of the applied herbicides by ownership, as well as the mean and the standard deviation for no-till and conventional till. No significant difference at 0.05 level was found in both no-till and conventional till with regard to the influence of ownership or rental on the rates of herbicides applied. Therefore, whether the farmer owns or rents the farm does not have any influence on the rates of herbicides applied since those who own and those who rent apply similar rates of herbicides to their no-till and conventional till acreages.

Table 4.19. ANOVA Results of Herbicides by Ownership (No-Till Only)

Herbicide	Demo Variable	N	Levels	Mean (lbs/ acre) (i.a.)	Std.	F	Value
Atrazine	Ownership	23	Own	2.7613	1.9290	0.7271	0.4876
		11	Rent	2.0800	1.1249		
		28	Both	2.6464	1.3953		
Cyanazine (Bladex)	Ownership	9	Own	2.4378	1.3007	0.5375	0.5928
		1	Rent	2.0000	1.0365		
		12	Both	2.8750	1.1294		
Metolach lor (Dual)	Ownership	7	Own	2.0000	0.0000	0.0680	0.9345
		1	Rent	2.0000	0.7379		
		10	Both	2.1000	0.5393		
Paraquat (Gramoxone Super)	Ownership	10	Own	0.6375	0.2958	0.2158	0.8081
		4	Rent	0.7031	0.5386		
		6	Both	0.7500	0.2372		
Glyphosate (Roundup)	Ownership	15	Own	1.6500	0.4205	2.5566	0.1015
		2	Rent	2.2500	1.0607		
		7	Both	1.5000	0.0000		
Alachlor (Lasso)	Ownership	12	Own	2.2708	0.6524	0.6076	0.5525
		5	Rent	1.9000	0.5477		
		11	Both	2.1136	0.6649		

a.i. = active ingredient

Table 4.20. ANOVA Results of Herbicides by Ownership (Conventional Only)

Herbicide	Demo Variable	N	Levels	Mean (lbs/ acre) (a.i.)	Std.	F	Value
Atrazine (PREM)	Ownership	9	Own	3.2044	2.1754	0.7074	0.5018
		5	Rent	2.2800	0.9550		
		16	Both	2.6812	0.0400		
Cyanazine (Bladex)	Ownership	6	Own	2.5317	1.5031	0.0099	0.9225
		7	Both	2.6143	1.4815		
Metolachr low (Dual)	Ownership	3	Own	2.0000	1.-000	0.0075	0.9925
		1	Rent	2.0000	.00		
		8	Both	1.9375	0.9425		
Alachlor (Lasso)	Ownership	8	Own	2.3428	0.5165	0.3802	0.6901
		3	Rent	2.3333	0.5774		
		7	Both	2.1357	0.4130		

a.i. = active ingredient

Research Question 5

Research Question 5: To what extent does farming status (full-time or part-time) influence the rate of herbicides applied in no-till corn acres?

The respondents were asked whether or not they were full-time or part-time farmers. The t-test was used separately for no-till and conventional till responses to determine whether or not significant differences exist in the rates of herbicides applied by full-time and part-time farmers.

Tables 4.21 indicates the t-test result of applied herbicides by farming status for no-till corn.

As shown in Tables 4.21, no significant difference at 0.05 level was found in no-till. Consequently, whether a farmer is full time or part time did not have any influence on the rate of herbicides applied since full-time and part-time no-till corn farmers applied similar rates of herbicides.

Research Question 6

Research Question 6: To what extent do farmers; environmental awareness influence the rate of herbicides they applied?

The respondents were asked whether or not they think agricultural practice is a significant source of

Table 4.21. T-Test Result: Herbicides (active ingredients) by Farming Status (Full-Time vs. Part-Time) (No-till Only)

Herbicide	Demographic Variable	N	Levels	Mean (lbs/ acres) (a.i.)	Std.	T-Value	2-Tail Prob.
Atrazine	F-Status	50	Full-Time	2.5958	1.680	0.10	0.924
		12	Part-Time	2.5583	1.063		
Cyanazine (Bladex)	F-Status	19	Full-time	2.4863	1.114	0.18	0.865
		3	Part-Time	2.400	0.693		
Metolachlor (Dual)[a]	F-Status	16	Full-Time	2.0625	0.574	0.0	0.0
		2	Part-Time	2.0000	0.000		
Paraquat (Gramoxone Super)[a]	F-Status	18	Full-Time	0.7083	0.331	0.0	0.0
		2	Part-Time	0.4688	0.133		
Glyphosate (Roundup)	F-Status	16	Full-Time	1.7344	0.528	1.78	0.096
		7	Part-Time	1.5000	0.000		
Alachlor (Lasso)	F-Status	24	Full-time	2.2083	1.637	1.63	0.167
		4	Part-Time	1.7500	1.500		

a.i. = active ingredient

[a]t-statistic could not be computed due to few subjects in group.

environmental pollution in their county relative to other sources of pollution such as industries.

Table 4.22 and 4.23 show the t-test results of applied herbicides by level of environmental awareness (illustrated by "yes" and "no") for no-till and conventional tillage.

No significant differences were found with regard to the amount of herbicides applied and the level of environmental awareness of the respondents. The result indicates that whether a farmer saw agricultural practices as significant sources of environmental pollution or not did not influence the rates of herbicides applied since the two groups applied similar rates of herbicides.

Research Question 7

Research Question 7: To what extent does income influence the rate of herbicides applied by the farmers?

The respondents were asked to indicate their after-taxes annual farm income from a list ranging from "less than $10,000" to "above $60,000." Respondents were least willing to answer this income-related question. The data show that there were 27 nonresponses out of the total 92 farmers.

Table 4.22. T-Test Result: Herbicides (active ingredients) by Environmental Awareness (No-till Only)

Herbicide	Demographic Variable	N	Levels	Mean (lbs/ acres) (a.i.)	Std.	T-Value	2-Tail Prob.
Atrazine	Environ.	25	Yes	3.0196	1.941	1.66	0.104
		35	No	2.2857	1.236		
Cyanazine (Bladex)	Environ.	5	Yes	2.0380	1.161	-1.32	0.232
		15	No	2.8167	1.097		
Metolachlor (Dual)	Environ.	3	Yes	2.0000	0.0000	-0.43	0.671
		14	No	2.0714	0.616		
Paraquat (Gramoxone Super)	Environ.	4	Yes	0.6563	0.359	-0.18	0.867
		16	No	0.6914	0.326		
Glyphosate (Roundup)	Environ.	5	Yes	1.5000	0.000	-1.76	0.096
		19	No	1.6974	0.490		
Alachlor (Lasso)	Environ.	12	Yes	2.3750	0.517	1.75	0.092
		15	No	1.9667	0.694		

a.i. = active ingredient

Table 4.23. T-Test Result: Herbicides (active ingredients) by Environmental Awareness (Conventional Only)

Herbicide	Demographic Variable	N	Levels	Mean (lbs/ acres) (a.i.)	Std.	T-Value	2-Tail Prob.
Atrazine (PREM)	Environ.	10	Yes	3.3400	1.946	1.32	0.210
		19	No	2.4600	1.094		
Cyanazine (Bladex)[a]	Environ.	2	Yes	2.3200	2.376	0.0	0.0
		9	No	2.6227	1.367		
Metolachlor (Dual)[a]	Environ.	1	Yes	2.0000	0.000	0.0	0.0
		11	No	1.9545	0.789		
Alachlor (Lasso)	Environ.	9	Yes	2.4111	0.553	1.29	0.220
		8	No	2.1250	0.354		

[a]t-statistic could not be computed due to few subjects in group.

a.i. = active ingredient.

Table 4.24 and 4.25 illustrate the Analysis of Variance result of herbicides by income levels in no-till and conventional till.

As indicated in Tables 4.24 and 4.25, there were no significant differences in both no-till and conventional till with reference to the influence of income on the rate of herbicides applied. The only significant difference was found in alachlor application in no-till. The result showed that mid-income farmers applied more alachlor than high or low income corn farmers. Besides the type of weed which may have resulted in more alachlor applied by mid-income farmers, it could also be that the mid-income farmers were new (first or second year) to no-till. According to the Ingham County District Soil Conservationist, "it has been shown that first-and second-year no-till farmers usually apply more herbicides in those early years while the amount applied drops off in later years" (Hicks, 1989). For the most part, therefore, whether a farmer was of low, middle, or high income did not influence the rates of herbicides applied.

Table 4.24. One way Analysis of Variance (ANOVA) Result of Herbicides (Active Ingredient) by Income (No-till only)

Herbicide	Demo Variable	N	Levels	Mean (lbs/ acre) (a.i.)	Std.	F	Value
Atrazine	Income	13	<15,000	2.8223	1.7097	1.0549	0.3577
		15	15,000-24,999	2.8053	1.9762		
		15	>25,000	1.9980	1.5435		
Cyanazine (Bladex)	Income	3	<15,000	3.2000	1.3856	0.7087	0.5091
		5	15,000-24,999	2.1680	1.1988		
		9	>25,000	2.5278	1.1273		
Metolachlor (Dual	Income	3	<15,000	2.000	0.0000	1.0000	0.3966
		7	15,000-24,999	2.2857	0.7559		
		5	>25,000	1.8000	0.4472		
Paraquat (Gramoxone Super)	Income	5	<15,000	0.8250	0.4889	0.3534	0.7088
		5	15,000-24,999	0.6375	0.3137		
		6	>25,000	0.6875	0.2823		
Glyphosate (Roundup)	Income	7	<15,000	1.8214	0.5901	0.7001	0.5143
		5	15,000-24,999	1.5000	0.0000		
		4	>25,000	1.8750	0.7500		
Alachlor	Income	7	<15,000	2.000	0.5774	4.0734	0.0328*
		9	15,000-24,999	2.5278	0.5368		
		7	>25,000	1.8214	0.4261		

*Significant at the .05 level.

a.i. = active ingredients

Table 4.25 ANOVA Results of Herbicides by Income (Conventional Only)

Herbicide	Demo Variable	N	Levels	Mean (lbs/ acre) (a.i.)	Std.	F	Value
Atrazine (PREM)	Income	4	<15,000	2.1100	0.7269	0.4622	0.6376
		13	15,000-24,999	2.7308	1.9517		
		3	>25,000	3.3333	0.5774		
Alachlor (Lasso)	Income	2	<15,000	2.000	0.0000	07667	0.4878
		9	15,000-24,999	2.3833	0.5679		
		3	>25,000	2.0833	0.1443		
Cyanazine (Bladex)	Income	3	<15,000	3.2000	1.3856	0.5999	0.5748
		5	15,000-24,999	2.0080	1.4534		
		2	>25,000	2.2500	1.9092		
Metolachlor (Dual)	Income	2	<15,000	2.000	0.0000	1.3778	0.3129
		5	15,000-24,999	2.3000	0.9747		
		3	>25,000	1.3333	0.5774		

a.i. = active ingredient

Research Question 8

Research Question 8: To what extent does the size of the farm influence the rate of herbicides applied?

The respondents were asked to indicate how many acres of corn they planted separately in no-till and conventional till. The Pearson Moment Correlation Coefficient was used to determine if there was a statistically significant relationship between the size of the farm and the rates of herbicides applied.

Table 4.26 shows the result of the relationship between herbicide rates and the size of the farm in both no-till and conventional till.

As shown in Table 4.26, no significant differences at 0.05 level were found in both no-till and conventional till with regard to the influence of farm size on the rate of herbicides applied except for alachlor applications in no-till corn. The findings indicate that increase in farm size corresponded with increase in the rate of alachlor applied. The increase in alachlor applications with increase in farm size could be due to the presence of more herbicide resistant weeds which induced increases in herbicide rates applied. It could also be that the farmers were switching to no-till for the first time and decided to apply more to ensure

Table 4.26. Relationship Between Herbicide Rates with Size of Farm (No-till and Conventional)

	No-till			Conventional		
Herbicide	N	r	P-Value	N	r	P-Value
Atrazine	62	-0.0570	0.330	45	0.1320	0.194
Cyanazine (Bladex)	22	0.296	0.448*	15	0.1944	0.244
Metolachlor (Dual)	18	.0606	0.406	12	0.1357	0.337
Paraquat (Gramoxone Super	20	.0289	0.452	--	--	--
Glyphosate (Round-Up)	24	.0247	0.454	--	--	--
Alachlor (Lasso)	28	0.4879	0.004*	21	0.0845	0.358

*Significant at the .05 level.

returns on their investments, especially for land, labor, and other inputs such as herbicides, fertilizers, and machinery.

Research Question 9

Research Question 9: To what extent do years in continuous no-till corn influence the rate of herbicides applied?

The respondents were asked to indicate how long (in years) they have planted continuous no-till corn. The Pearson's Moment Correlation Coefficient was used to determine if there is a statistically significant relationship between the number of years a farmer has planted continuous no-till corn and the rates of herbicides applied by the farmer.

Table 4.27 shows the result of the relationship between years in continuous no-till corn and the rate of herbicides applied by the respondents.

Results on Table 4.27 shows that alachlor was statistically significant at 0.05 level in no-till application. This suggests that the more the years in continuous no-till corn, the more the rates of alachlor applied. This finding disagrees with an earlier finding which suggests that no-till farmers usually apply more herbicides in the early years while the amount of herbicides applied decline in later years. Although the

Table 4.27. Relationship between Herbicide Rates (Active Ingredients) with Years of Experience with Continuous No-Till Corn

Herbicide	N	r	P-Value
No-Till			
Atrazine	62	-0.0481	0.355
Cyanazine (Bladex)	22	0.1139	0.307
Metolachlor (Dual)	18	0.0946	0.354
Paraquat (Gramoxone Super)	20	0.1409	0.277
Glyphosate (Round-Up)	24	0.0688	0.375
Alachlor (Lasso)	28	0.4337	0.011*

*Significant at the 0.05 level.

finding disagrees with an earlier finding, it could be peculiar only with continuous no-till corn.

Doub et al. (1988) found that the "control of the dominant annual grass species, large crabgrass, by alachlor declined to less than 50% by the fifth year of continuous no-till corn." However, Doub et al. (1988) reported that the "control of large crabgrass by metolachlor remained greater than 80% throughout the study, although metolachlor allowed establishment of a greater fall panicum population. . . ." Doub et al. (1988) concluded that while "alachlor and metolachlor provide excellent annual grass control the first year, both display deficiences when repeatedly used in continuous no till" and that "high large crabgrass populations associated with continuous no-till management may have been responsible for the low control by repeated alachlor applications."

Triplett Jr., and Lytle (1972) found that only combinations of herbicides proved most satisfactory in eliminating weed and that "annual weed populations shifted rapidly with different herbicide systems."

In summary, Chapter IV discussed the general characteristics and observations from the study as well as a more detailed report of the findings based on the research questions.

CHAPTER V

SUMMARY, CONCLUSION, DISCUSSION, AND RECOMMENDATIONS

Summary

Purpose

This study explored the reported herbicide application rates applied by no-till corn farmers in nine Michigan counties and whether or not the farmers were applying herbicides according to recommended rates on container labels and what influenced them to apply the rates of herbicides they applied.

Another primary objective of this study was to determine whether or not the same farmers applied the same rates of herbicides to both their no-till and conventional corn acreages.

Research Questions

The following research questions were addressed in the study:

Research Question 1. To what extent do herbicides applied by no-till corn farmers in nine Michigan counties conform with the recommended rates on container labels?

Research Question 2. To what extent do herbicide rates applied by the same no-till corn farmers conform with herbicide rates they apply on conventional-till corn acres?

Research Question 3. To what extent does the level of education, land ownership, farming status, (full time versus part time) environmental awareness, income, farm size, and years in continuous no-till corn influence the rate of herbicides applied by the farmers?

It is worth noting that in this study, the applied herbicide formulations in liquid, wettable powder, and water dispersible granule or dry flowables were converted into active ingredients.

Population and Sample

There were 376 farmers listed by the U.S. Soil Conservation Service as no-till corn farmers in the nine counties under study. The counties are Berrien, Cass, Clinton, Eaton, Hillsdale, Ingham, Ionia, Isabella, and Lenawee. Out of the 376 listed farmers, 92 choose to participate in this study by voluntarily completing a mail questionnaire.

Methodology

A survey questionnaire comprised of 29 questions relating to practice, institutions, environmental/ attitudinal and demographic factors was used to solicit answers from the participants. A mail survey was used with follow-up reminders.

Statistical Package for the Social Sciences (SPSSX) was used to analyze the data obtained from the survey. Simple descriptive statistics ranging from frequencies, percentages, means, and standard deviation were used to analyze the results. In addition, the t-test, analysis of variance (ANOVA) and Pearson's Moment Correlation Coefficient were utilized in analyzing data and drawing conclusions.

The following is a summary of some of the findings based on the response of the 92 respondents that provided useable questionnaires.

Size of Farm

The average amount of no-till corn acreage per farm for the 92 farms was 151 acres. Out of the 92 respondents, 73 (or 79%) had less than 200 acres of no-till corn. Of the 92 respondents, 65 also planted conventional till corn. The average size of conventional corn acreage on the 65 farms was 154 acres.

Years in No-Till Corn

About one-half of the 92 respondents have planted no-till corn for five years or less. However, 80 (or 86%) of the farmers have planted no-till corn for eleven years or less.

Most Common Soil Textures

The three most common soil textures identified by the respondents that best describes their no-till corn acreage are clay loam, sandy loam, and loam. They comprised 33.7%, 27.2%, and 20.7% of the responses, respectively.

Ownership of No-Till Acres

Slightly less than one-half of the 92 respondents owned their no-till corn acres. Specifically, 43 (or 46%) owned their no-till acres, while 14 (or 15%) rented from others. Thirty-five respondents (or 38%) both owned and rented their no-till corn acres.

Are More Herbicides Applied In No-Till than in Conventional Till?

Slightly over one-half of the respondents agreed that more herbicides are applied in no-till. That is, 54 (or 58.7%) agreed that more herbicides are applied in no-till. When asked if they personally applied the same rates of herbicides each year to the same no-till and conventional acreages, 49 (or 53%) indicated they applied the same rates every year.

Summary of the Findings and Conclusions

Comparison Between Actual Rates of Applied Herbicides and the Recommended Rates

Research Question 1. To what extent do herbicides applied by no-till corn farmers in nine Michigan counties conform with the recommended rates on container labels?

Summary of findings: Overall, the 92 respondents reported that they applied herbicides below and within the range of recommended rates.

Of the atrazine applied in no-till corn, 73% was applied below and within the range of recommended rates, while 27% of the applied atrazine was applied above the range of recommended rates.

Of the cyanazine applied in no-till corn, 100% was applied within the range of recommended rates. Like cyanazine, 94.4% of the applied metolachlor was applied below or within the range of recommended rates and 5.6% was applied above the range of recommended rates.

Of the paraquat applied, 80% was applied below the range of recommended rates, while 20% of the herbicide was applied above the range of recommended rates.

In no-till, also, 87.5% of the applied glyphosate (Roundup) was applied within the range of recommended rates. Paraquat and glyphosate were not shown on Table 4.15 because they were not used by the respondents in conventional till and therefore cannot be adequately compared. Of the applied alachlor (Lasso), 86.0% was applied within the range of recommended rates, while 14.0% was applied below the range of recommended rates.

In corn under conventional tillage, 66.7% of preemergence atrazine was applied below or within the range of recommended rates. Similarly to no-till, 100% of the applied cyanazine in conventional till corn was applied below or within the range of recommended rates. Of the alachlor applied in conventional till, 100% was applied below or within the recommended rates.

Conclusion: The reported rates of herbicides applied by the 92 respondents were mostly below or within the range of recommended rates on container labels.

Comparison Between Rates of Herbicide Applied in No-Till Corn and Rates of Herbicide Applied in Corn Under Conventional Tillage

Research Question 2. To what extent do herbicide rates applied by the same no-till corn farmers conform with herbicide rates they applied on conventional till corn acres?

Summary of Findings: The data show there was conformity in herbicide application rates for the herbicides applied namely atrazine, alachlor, cyanazine and metolachlor applied in both no-till and conventional till. No statistically significant differences were observed for the reported rates applied in corn under no-till and conventional till.

Conclusion: Contrary to the 54 respondents (or 58.7%) and other sources that believe that more herbicides are applied to no-till than to conventional till, this study showed that similar rates of herbicides were applied in both no-till and conventional till.

Influences of Selected Demographic Variables on Applied Herbicide Rates

Research Question 3. To what extent does the level of education influence the rate of herbicides applied by the farmers in no-till and conventional till corn?

Summary of Findings: A t-test was used to determine if statistically significant differences existed between the less-educated and the more-educated respondents with regard to the rates of herbicides they applied. The result showed that there were no significant differences at 0.05 level between the less-educated and the more-educated respondents in regard to the rates of herbicides applied by the respondents.

Conclusion: The level of education of the respondents did not make any difference in terms of influencing the rate of herbicides applied. The rates of herbicides applied by the less educated and the more educated were similar and no one group applied either more or less than the other.

Research Question 4. To what extent does ownership or rental of farmland influence the rate of herbicides applied by the farmers in no-till and conventional till?

Summary of Findings: Analysis of Variance was used to test for statistically significant differences in the rates of herbicides applied between those who owned the land they operated, those who rented the land they operated, and those who did both. The result showed there was no significant difference among those who owned and operated their land, and those who rented land from others, and those who did both.

Conclusion: Whether a farmer owned his farm or rented it or both did not have any influence on the rates of herbicides applied.

Research Question 5: To what extent does farming status (full-time or part-time) influence the rate of herbicides applied in no-till corn acres?

Summary of Findings: The t-test was used to determine if statistically significant differences exist in the rates of herbicides applied by full-time farmers and part-time farmers to no-till corn acreage. The result showed that no significant differences were observed in no-till for full-time and part-time farmers in regard to the rates of herbicides they applied.

Conclusion: In all cases, the rate of herbicides applied in no-till did not depend on whether the farmer is a full-time or part-time farm operator, since both full-time and part-time farmers applied similar rates of herbicides.

Research Question 6: To what extent do farmers' environmental awareness influence the rate of herbicides they applied in no-till and conventional till corn?

Summary of findings: A t-test was used to determine if statistically significant differences exist in the rate of herbicide applied by the more environmentally-aware respondents from the less-environmentally aware respondents. In both no-till and conventional till herbicide applications, no statistically significant difference was found between the more environmentally aware respondents and the less-environmentally aware respondents with regard to the rates of herbicides they applied.

Conclusion. Whether a farmer was environmentally aware or not that pesticides are significant sources of environmental pollution in their county did not have an influence on the rates of herbicides they applied.

Research Question 7: To what extent does income influence the rate of herbicides applied by the farmers in no-till and conventional till corn?

Summary of findings: Analysis of variance was used to determine if statistically significant differences exist among high, middle, and low income group farmers in the study with reference to their herbicide application rates for the different herbicides. In general, there was no significant difference among the three income groups with regard to the rates of herbicides they applied. The only exception was alachlor (Lasso) application in no-till where the middle income farmers applied higher rates. An unnamed District Conservationist in one of the counties surveyed suggested that is not uncommon that mid-income farmers would apply higher rates of alachlor because "mid-income to high-income farmers tend to always include a fall grass herbicide such as alachlor or metolachlor."

Conclusion: In almost all cases, income level had no influence on the rates of herbicides applied.

Research Question 8: To what extent does the size of the farm influence the rate of herbicides applied in no-till and conventional till?

Summary of Findings: The Pearson's Moment Correlation Coefficient was used to determine if there were statistically significant relationships between the size of the farm and the rate of herbicides applied. No significant relationships were found with regard to the size of the farm and the rates of herbicides applied. The only exception was alachlor application in no-till which was found to have a statistically significant relationship with the size of the farm. Consequently, as farm size increased, the rate of applied alachlor increased. This exception may have been due to the presence of more herbicide resistant weeds.

Conclusion: In almost every instance, the size of the farm did not have any influence on the rate of herbicides applied.

Research Question 9: To what extent do years in continuous no-till corn influence the rate of herbicides applied?

Summary of findings: The Pearson's Moment Correlation Coefficient was used to determine if statistically significant relationship exists between the number of years in continuous no-till corn and the rates of herbicides applied. The result indicated a statistically significant relationship for alachlor applications at 0.05 level.

Conclusion: Those respondents who had more years in continuous no-till corn applied higher rates of alachlor. This again may be attributed to changes in types of weed and the inability of alachlor to control the weeds.

Discussion

This section focuses on the comparison and contrast between some of the findings in the study and the findings of some other similar studies related to soil conservation. It is worth noting that these other studies did not deal specifically with chemical or herbicide application.

Sources of Information

This study found that the four primary sources of information for herbicide application by the respondents were: container labels, chemical and fertilizer salespeople, the Soil Conservation Service, and the Cooperative Extension Service. This is contrary to the traditional farming communities where those seeking information relied on personal primary sources of information such as fellow farmers they interact with on a face-to-face basis (Kirkalas, 1983). Of the 92 respondents in this study, 19 (or 20.6%) indicated farmers, friends, or neighbors as "very important" source of information compared to 61 (or 66.3%) which noted container labels as very important.

The discrepancy in the sources of information could be explained by the

> proliferation of the mass media, the ease of transportation, and the continuing development of electronic information generating, processing, communicating, and storing systems which has made rural residents more comfortable with the secondary impersonal information sources (Bradshaw and Blakely, 1979).

Although the respondents in this study were not asked to state reasons why they choose the sources of information they selected for the herbicides they applied, one of two information models or both could be used to explain why one chooses one source of information over another. According to Hardy (1982), the first model says that one will use a source of information that provides the perceived highest quality of information. The second model postulates that the information seeker chooses a source of information that minimizes costs regardless of the quality of the information. Birkel and Repucci (1983) found that accessibility and speed factors seem to be dominant influences on the choice of information source rather than the amount of quality of the information.

Impact of Educational Level

One would have expected the less educated respondents to apply more herbicides than recommended because they would have less access to information, poorer management skills, and would less understand the dangers of herbicide misuse and the potential impacts on the environment, especially the groundwater and the surface water.

The data indicated that there was no statistically significant difference in the rate of herbicide application between the less educated and the more educated respondents where the less educated were those with high school certificate and less, while more educated had more than high school certificate. On the contrary, soil conservation studies by Ervin and Ervin (1982), Pampel and Van Es (1977), and Nowak and Korsching

(1981) and Carlson et al. (1977, 1981) found that education has a positive influence on conservation efforts because the more highly educated farmers may have better access to information and better management skills (Kerns and Kramer, 1985).

Impact of Tenure

One would expect those who own the land they cultivate to be more judicious in herbicide application and to be stewards of the land. Therefore, one would expect those who own their land to apply herbicide according to the recommended rates.

This study showed that there was no significant differences between those who owned their farm and those who rented in regard to the amount of herbicides they applied.

Nowak and Korsching (1981) found a positive relationship between the degree of ownership and the use of less erosive practices. However, Kerns and Kramer (1985) did not find any such positive relationship in their study of farmers' attitudes toward nonpoint pollution with regard to control and participation in cost-share programs.

Income and Its Impact

One would expect the wealthier farmers to apply herbicides according to recommended rates. This assumption is based on the fact that wealthier farmers are more likely to own or rent the most appropriate and efficient farming tools and machinery, especially those used in dispensing herbicides in the farm. Carlson et al. (1981) found a positive association between gross income and conservation practices use. Baron (1981) also reported a positive relationship between investment in conservation and farm income. Similarly, Dillman et al. (1978) found a slightly higher gross income for Soil Conservation Service cooperators than noncooperators.

Contrary to studies reporting positive relationship between higher income and the use of conservation practices, this study found that overall there was no significant difference among the lower, middle, or higher income groups with regard to the rates of herbicides applied by the farmers. The only exception was the application of alachlor in no-till where middle income farmers apparently applied higher rates of herbicides. An explanation for the higher alachlor rates is that mid-income to high-income farmers tend to apply a fall grass herbicide such as alachlor. Essentially, the level of income had no influence on the rates of herbicides applied.

Impact of Full-time and Part-time Farm Work

Kerns and Kramer (1985) found that

> whether the farmer was a full-time or part-time farmer did not have a significant impact on the application for Rural Clean Water Project (RCWP) funding, a PMP cost-sharing program operated by the United States Agricultural Stabilization and Conservation Service (ASCC).

This study found that in all cases in no-till, the rate of herbicides applied by the farmers did not depend on whether the farmer was full time or part time.

Impact of Farm Size

Several studies including Wagner et al. (1981), Carlson et al. (1981), Coughenour and Kothari (1981), Earle et al. (1979) and Kerns and Kramer (1985) have found a strong relationship between farm size and the adoption of conservation practices.

According to Wegener et al. (1981) a strong relationship is expected between the size of the farm and the use of conservation practices because of (1) flexibility expected on the part of operators of large farms in their decision-making process, (2) access to discretionary resources, (3) more opportunity to experiment with best management practices on a small-scale basis, and (4) the possibility that large operators are better able to deal with the risk and uncertainty often associated with adopting new agricultural practices.

Contrary to the above-cited studies in regard to farm size, this study found in almost all cases that the size of the farm has no influence on the rates of herbicides applied by the farmers.

Considerations for Nonrespondents

Due to the fairly large number of nonrespondents (and unusable responses), an attempt was made to obtain information on whether or not nonrespondents would have given similar or different responses compared to the findings based on responses offered by the respondents.

The nine research questions in this study and the summary of the general findings were sent to the District Conservationists (DC's) in the nine counties studied. The DC's were asked to offer their feedback. The essence of the feedback as stated in the cover letter to the DC's was to ascertain whether or not the responses and findings would have been similar or different from responses that would have been received from the nonrespondent group.

With a few exceptions, the DC's agreed with all the findings. For example, seven of the DC's indicated that their experience with the farmers would support the findings that most of the farmers applied herbicides (atrazine, cyanazine, metolachlor, and alachlor) below and within the range of recommended rates. Two of the DC's felt that the 27% who applied atrazine above the recommended rate was not realistic. They felt the percentage that over applied should have been less. One in particular felt it should have been in the 5-10% range.

Three other findings with opposing responses are worthy of note. All the DC's agreed with the general findings that income levels of the farmers did not influence the rates of herbicides applied. While seven DC's agreed with the finding which showed mid income no-till farmers applied more alachlor than low or high income, no-till farmers, two of the DC's disagreed indicating they could not see why income levels would make any difference. Among the seven DC's that agreed, one noted that "mid-income to high income farmers tend to always include a fall grass herbicide such as metolachlor or alachlor."

Overall, this study found that the size of the farm did not influence the rate of herbicides applied. The only exception was alachlor application in no-till where increase in farm size corresponded with increase in alachlor applied. The implication is that the larger the size of the farm, the more the rate of alachlor applied.

Three DC's disagreed while six agreed although none gave an explanation for their views.

Finally, this study found that there was no significant relationship between the number of years in continuous no-till and the rates of herbicides applied. The only exception was in alachlor application where higher rates of application corresponded with more years in continuous no-till. Six DC's agreed with the findings. Four disagreed, stating essentially that the rates applied "drop with increasing number of years of no-till."

In conclusion, it is noteworthy that the DC's responses were generally in support of the research findings. However, there were a few points of disagreement which suggest that such areas of disagreement deserve further inquiries or studies.

Limitations and Recommendations for Future Study

This study concentrated on the nine primary no-till corn counties in Michigan based on the 1987 data. The rather low response rate from the nine counties constitute a limitation since the information from nonrespondents may have had an impact on the data analysis and conclusion of the study.

Certain factors may have contributed to the low response rate. This includes:

1. No-till corn farmers may not have been in their best mood to fill out questionnaires especially following the flood of 1986 and the drought of 1987.

2. Complete list of no-till corn farmers may not have been provided by the District Soil Conservationists. This was obvious because while most of the District Conservationists were ready with their list, a few wrote down only the names of the no-till corn farmers they could remember at the request of the researcher.

3. Parts of the lists obtained were outdated. This also was obvious from the responses. Most of the nonvalid responses were farmers who do not plant no-till corn. A few of the letters were returned because they were unclaimed due to change in address. A few other farmers indicated they have not planted no-till corn in the past three years.

Some of these problems, such as outdatedness of the list and the inclusion of someone other than the desired respondent, are well documented by Dillman (1978).

Recommendations

To further explore some of the questions addressed by this study, the following suggestions are made for further research:

1. The farmers studied should be studied over time or again after a few years to see whether or not their herbicide application remained the same.

2. A similar, more encompassing study, including many more counties in Michigan should be undertaken to see if the responses and results are different from this study.

3. A similar study emphasizing conventional corn farmers should be undertaken and the result compared to this study.

4. Other cash crop farmers, such as soybean and wheat farmers, should be studied to explore their herbicide application habits, since such farmers also use large amounts of herbicides, such as alachlor, metolachlor, and glyphosate which have the potential of contaminating surface and groundwater.

5. A study should be done to look for relationship between the application conditions in the counties studied and the presence or absence of the applied herbicides, specifically atrazine cyanazine, metolachlor, gramoxone super, glyphosate, and alachlor in their groundwater and surface water systems.

6. Similarly, those farmers who grow other cash-producing agricultural plants, such as grapes, apples, oranges, lettuce, and strawberries should be studied to

explore if they are applying herbicides according to recommended rates.

7. A similar study such as this should be done with an emphasis on a research question to find out if the age of the farmer has any influence on the rate of herbicides applied. Are younger farmers, for example, applying more or less herbicides than older farmers?

8. To improve on the response rate, a telephone survey or a person-to-person interview might be considered for a similar research, especially if the financial resources are available.

9. Studies need to continue to explore if small- or large-scale farming could survive with little or no herbicides, since there is wide concern by farmers, scientists, environmentalists, and the general public about environmental consequences of herbicides and other pesticides.

10. A similar, but more detailed, study should be done to compare specifically the recommended rates of herbicide for each formulation of herbicide with each specific soil texture and compare the results with the results of this study. This study set the active ingredients within a range that considered the formulation of the herbicide, the organic matter content, and soil texture.

Generalizability of Study

The findings of this study, such as whether no-till corn farmers are applying herbicides according to recommended rates on container labels and whether there are significant differences between the rates of herbicides applied to no-till and conventional till corn acres will be educationally and professionally beneficial. Educators and students in soil conservation and management, for example, could use the results for research and reference purposes. Federal, state, and local district agencies, such as the United States Department of Agriculture (U.S.D.A.), Michigan Departments of Agriculture and Natural Resources, the Cooperative Extension Service Agents, and District Soil Conservationists who work directly with the farmers, will also benefit. This study will benefit these officials, for example, by allowing them to make better predictions and projections on herbicide use in farms especially no-till farms in their counties.

In addition to its use by educators, soil conservationists, federal, and local officials and agencies, the findings of this study could be applied elsewhere, both nationally and internationally (as in the author's native country of Nigeria). The federal and state governments in Nigeria, in addition to multilateral organizations such as the World Bank, encourage small-scale farmers with "integrated rural development" packages including advice, improved infrastructure better inputs and other assistance. Similarly, the federal government encourages large-scale commercial farmers to boost their agricultural production by liberalizing taxes, credit, and investment opportunities (Hear, 1985). It is not known how much information or guidance the commercial and peasant farmers obtain in applying inputs, such as fertilizer and herbicides. It is also not known whether the farmers apply agricultural chemicals according to recommended application rates on container labels.

The findings of this study would also be beneficial to chemical companies that manufacture herbicides. For example, it would be of interest for chemical companies to find out if farmers are applying herbicides according to recommended rates on container labels.

Farmers may benefit from this study. The results could lead to more effective herbicide management on farms. The findings could help to reduce and control one of the major agricultural sources of nonpoint source pollution. Better herbicide management will also help to cut farm costs by saving time, labor, and equipment costs. The general public may also benefit because better management of herbicides and other farm chemicals could lead to a reduction in potential health costs and other costs resulting from surface and groundwater contamination.

Finally, this study will be beneficial to federal, state, and local agencies, such as the United States Department of Agriculture, the Environmental Protection Agency, Michigan Department of Agriculture (MDA), and the Michigan Department of Natural Resources, as well as county extension agents and District Soil Conservationists. This study focuses on the most widely used herbicides in no-till and conventional corn acreages in the nine counties studied. This information would help to identify where testing of one or more of these commonly applied herbicides should occur (in the study area) rather than arbitrarily choosing to test for herbicides which might not be commonly used, and therefore, not likely to persist or be present in groundwater or surface water.

APPENDICES

APPENDIX A

SAMPLE LETTER TO RESPONDENTS

MICHIGAN STATE UNIVERSITY

DEPARTMENT OF RESOURCE DEVELOPMENT
NATURAL RESOURCES BUILDING

EAST LANSING • MICHIGAN • 48824-1222

April 20, 1988

Dear No-till Farmer:

Herbicides and other chemicals have been shown to be extremely important in raising crop productivity. There is concern about proper management of herbicides and other chemicals to minimize and prevent environmental pollution, especially groundwater and surface water contamination. While some studies show that pesticides are leaching into the groundwater, others show that there is no difference in pesticide leaching between no-till and conventionally (clean) tilled acreages.

I (Ernest) am a graduate student in the above Department and my interest in soil and water conservation triggered this study. Although I am the principal researcher, others such as Mr. Dwight Quisenberry of the SCS have been helpful as well as interested in my research topic.

The purpose of this study is to determine the actual rates of herbicides applied in no-till corn acreage in Michigan and factors influencing application rates. It is hoped that the results from this effort will enhance proper and cost-efficient management of herbicides and chemicals for no-till corn producers such as yourself and other Michigan farmers.

You have been chosen from a random sample of no-till corn farmers from nine major no-till corn counties in Michigan. You may be assured of complete confidentiality. Your name is not required in your response. An identification number has been used for mailing purposes so that your name may be checked off the mailing list when your response is returned. A summary of the results of this study will be sent to you at your request.

For the purposes of this study, no-till is where the soil is left undisturbed prior to planting. Planting is completed in a narrow seedbed or slot created by a planter or drill. Weed control is accomplished primarily with herbicides and at least 30% of the soil surface is covered by residue after planting.

Any questions you have will be gladly answered. Please call or write if need be. A collect call will be accepted at my home. The telephone numbers are (517) 355-7248 (home) and (517) 355-6967 (office). Also feel free to contact your Soil Conservation District Conservationist or your local Agricultural Extension agent if you have any questions. Kindly return your response in the enclosed, stamped, self-addressed envelope by May 12. Thank you for your assistance.

Sincerely,

Dwight Quisenberry
State Agronomist
USDA, East Lansing, MI

Ernest Ndukwe
Graduate Student
Department of Resource Development

EN: cld
Enclosure

APPENDIX B

QUESTIONNAIRES (1988 AND 1989)

1988

Section I: Questions Relating to Practice

1. Have you used herbicides in no-till corn acreage in the past three growing seasons?

   (1) Yes
   (2) No

2. In addition to no-till, did you raise conventional till corn?

   (1) Yes
   (2) No
   (If No, please go to Question 4)

3. How many acres of corn did you plant in 1987?

   (1) Acres of No-till ________ acres
   (2) Acres of Conventional till ________ acres

4. Is your no-till corn acreage in one contiguous area (that is, in one uninterrupted area?)

   (1) Yes
   (2) No

5. How long have you had continuous no-till corn?

   Years ______________ (please specify)

6. How long have you planted no-till corn?

   Years ______________ (please specify)

<u>Select a typical no-till corn field on your farm and answer the following questions:</u>

7.1 For each method of application, please list the name(s) of the herbicide(s), the formulations, and the rate of application that you applied to this field in 1987.

	Herbicide	Formulation[a]	Rate[b]
Preemergence	______	______	______.
	______	______	______.
	______	______	______.
	______	______	______.
Postemergence	______	______	______.
	______	______	______.
	______	______	______.

[a] Wettable Powder (80W), Liquid (4L), Dry Flowable (DF) etc.
[b] Amount of formulated herbicide per acre (quarts/acre, pounds/acre, etc.)

7.2 In this same field, if you had used conventional tillage, what herbicides, formulations, and rates would you have selected?

	Herbicide	Formulation[a]	Rate[b]
Preplant Incorporated	______	______	______.
	______	______	______.
	______	______	______.
	______	______	______.
Preemergence	______	______	______.
	______	______	______.
	______	______	______.
	______	______	______.
Postemergence	______	______	______.
	______	______	______.
	______	______	______.
	______	______	______.

[a] Wettable Powder (80W), Liquid (4L), Dry Flowable (DF) etc.
[b] Amount of formulated herbicide per acre (quarts/acre, pounds/acre, etc.)

8. In what year was the last soil test conducted on your no-till corn acreage?

______________________________ (please indicate)

9. What is the soil pH in the field?

______________________________ (please indicate)

10. Which of the following best describes the most common soil texture in this field?
(Please circle one)

(1) Clay
(2) Clay loam
(3) Loam
(4) Sandy loam
(5) Loamy sand
(6) Sand
(7) Muck

11.1 Have you had your soil organic matter level tested for this field?

(1) Yes
(2) No

11.2 What do you think is the organic matter content in this no-till field?

(1) < 1/2%
(2) 1/2 - 1%
(3) 2%
(4) 3%
(5) 4%
(6) 5%
(7) Over 5%

12. What is the average percent slope of this (no till) field?

______________________________ (please indicate)

13. Do you own or rent your no-till acres?
(Please circle one)

(1) Own
(2) Rent
(3) Both

Institutional Questions

14. How often do you visit with your Cooperative Extension or Soil Conservation Personnel in the Average month? (Please circle one)

    (1) < 2 times
    (2) 2-4 times
    (3) 5-7 times
    (4) 8-10 times
    (5) Over 10 times

15. How often do you have telephone consultations with your Cooperative Extension or Soil Conservation Service Personnel in the average month? (Please circle one)

    (1) < 2 times
    (2) 2-4 times
    (3) 5-7 times
    (4) 8-10 times
    (5) Over 10 times

16. Rate with an X the importance of the following in terms of your sources of information for herbicide or chemical application. V = Very Important; M = Moderately Important; S = Some Importance; N = Not Important

	V	M	S	N
(a) Soil Conservation Service				
(b) Cooperative Extension Service				
(c) Soil Conservation District Directors				
(d) Container Labels				
(e) Farmers, Friends, Relatives, or Neighbors				
(f) Chemical and Fertilizer Sales People				
(g) Farm magazines and newspapers				
(h) Equipment Company Representatives				
(i) Radio or television programs				
(j) Local newspaper(s)				

Environmental/Attitudinal Questions

17. There is an on-going debate that more herbicides are applied in no-till compared to conventional tillage. Do you believe that more herbicides are applied in no-till than in conventional tillage?

    (1) Yes
    (2) No

18. From your experience, do you think that you apply the same rates of herbicide to the same acreages each year?

    (1) Yes
    (2) No

19. Rate with an X the following in order of importance as reason(s) for the amount of herbicides you applied in your no-till corn. V = Very Important; M = Moderately Important; S = Some Importance; N = Not Important

	V	M	S	N
(1) Desire to increase crop Production				
(2) Desire to increase farm profitability				
(3) Type of weed on your corn acreage				
(4) Advice from local Soil Conservation District				
(5) Advice from local Cooperative Extension Agent				
(6) Advice from Chemical and Fertilizer sales agents				
(7) Personal Farming habits				
(8) Other ______________ (Please specify)				

20. Rate with an X the following in terms of factors that would cause you to use less herbicide than you used in 1987.

	V	M	S	N
(1) Higher cost of herbicides this year				
(2) Personal concern about potential injury from herbicide application				
(3) Concern for surface and groundwater				
(4) Concern for potential rule violation				
(5) Advice from chemical salesperson				
(6) Advice from a fellow farmer				

21.1 Studies have shown that there is concern about potential health risks to farm families, neighbors, and others resulting from agricultural chemicals, pesticides, and fertilizers. In terms of your own family and neighborhood, do you think such concerns are justified?

(1) Yes
(2) No
(If No, please go to Question 22.1)

21.2 If such concerns are justified, how would you rank the concern? (Please circle one)

(1) Very concerned
(2) Moderately concerned
(3) Some concern
(4) Not concerned

22.1 Some studies have indicated that agricultural practices are significant sources of environmental pollution relative to other sources of pollution such as industries. Do you think that agricultural practices are significant source of environmental pollution in your county?

(1) Yes
(2) No
(If No, please go to Question 23)

22.2 How significant do you think environmental pollution from agricultural practices is in your county?

(1) Very significant
(2) Moderately significant
(3) Some significance
(4) Not significant

23. Recent studies in Michigan has shown that groundwater and surface water contamination could be a serious issue in some parts of the state. From your point of view, how serious do you think the issue of groundwater and surface water contamination are in your county?

(1) Very serious
(2) Moderately serious
(3) Somewhat serious
(4) Not serious

24. Some wells in Michigan have been contaminated by agricultural chemicals, such as nitrates. From your experience, how much of a problem do you think contamination of wells pose in your county?

(1) Very serious problem
(2) Moderately serious
(3) Somewhat serious
(4) Not serious

25. To what extent do you think well contamination in your county is caused by herbicides?

(1) A large extent
(2) Moderate extent
(3) Some extent
(4) None

Demographic Questions

26. Which of the following represents your highest level of education? (Please check one).

    (1) Less than high school
    (2) High school graduate
    (3) 2-Year vocational education degree
    (4) Some undergraduate college education
    (5) Undergraduate college degree
    (6) Some graduate studies
    (7) Graduate degree

27. Are you a full-time farmer?

    (1) Yes
    (2) No
    (If No, go to Question 29 below)

Definition: Full-time farmers are those who spend 100% of their time working on their farm and who derive all their income from the farm.

28. If yes (full-time farmer), which of the following categories represent your after-taxes annual farm income? (Please check one)

    (1) Less than $10,000
    (2) 10,001 - 14,999
    (3) 15,000 - 24,000
    (4) 25,000 - 34,999
    (5) 35,000 - 43,999
    (6) 44,000 - 49,999
    (7) 50,000 - 59,999
    (8) Above 60,000

29. What percentage of your combined annual income is derived from the farm?

    (1) Less than 10%
    (2) 10% - 19%
    (3) 20% - 29%
    (4) 30% - 39%
    (5) 40% - 49%
    (6) 50% - 59%
    (7) 60% - 69%
    (8) 70% - 80%
    (8) 80% and above

Thank you! Your cooperation is very much appreciated. Please return by May 12, 1988. Once gain, your name is not required on the form.

1989

Section 1: Questions Relating to Practice

1. Have you used herbicides in no-till corn acreage in the past three growing seasons?

   (1) Yes
   (2) No

2. In addition to no-till, did you raise conventional till corn?

   (1) Yes
   (2) No
   (If No, please go to Question 4)

3. How many acres of corn did you plant in 1988?

   (1) Acres of No-till ______ acres
   (2) Acres of Conventional till _____ acres

4. Did you plant the same number of corn acreage in 1988?

   (1) Yes
   (2) No

   If No, how many acres of corn did you plant in 1988?

   (1) Acres of No-till ______ acres
   (2) Acres of Conventional till ____ acres

5. Is your no-till corn acreage in one continuous area (that is, in one uninterrupted area)?

   (1) Yes
   (2) No

6. How long have you had continuous no-till corn?

   ____________________ years (please specify)

7 How long have you planted no-till corn?

   ____________________ years (please specify)

<u>Select a typical no-till corn field on your farm and answer the following questions:</u>

7.1 For each method of application, please list the name(s) of the herbicide(s), the formulations, and the rate of application that you applied to this field in 1987.

	Herbicide	Formulation[a]	Rate[b]
Preemergence	______	______	______.
	______	______	______.
	______	______	______.
	______	______	______.
Postemergence	______	______	______.
	______	______	______.
	______	______	______.

[a] Wettable Powder (80W), Liquid (4L), Dry Flowable (DF) etc.
[b] Amount of formulated herbicide per acre (quarts/acre, pounds/acre, etc.)

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	______	______	______.
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[a] Wettable Powder (80W), Liquid (4L), Dry Flowable (DF) etc.
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8. In what year was the last soil test conducted on your no-till corn acreage?

__________________________ (please indicate)

9. What is the soil pH in the field?

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10. Which of the following best describes the most common soil texture in this field? (Please circle one)

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27. Are you a full-time farmer?

    (1) Yes
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    (If No, go to Question 29 below)

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    (5) 35,000 - 43,999
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    (7) 60% - 69%
    (8) 70% - 80%
    (8) 80% and above

Thank you! Your cooperation is very much appreciated. Please return by May 12, 1988. Once gain, your name is not required on the form.

MICHIGAN STATE UNIVERSITY

DEPARTMENT OF RESOURCE DEVELOPMENT
NATURAL RESOURCES BUILDING

EAST LANSING • MICHIGAN • 48824-1222

March 14, 1989

Dear No-Till Farmer:

About a month ago, a questionnaire seeking your response on the actual rates of herbicides you apply in your no-till corn acreage was mailed to you.

Please accept my sincere thanks if you have already completed and returned your response. If not, please do so today. It is extremely important that your response be included in the study if the results are to be accurately represented.

If by some chance you did not receive the questionnaire, or if it got misplaced, please call me right now, collect (517/355-4047) and I will send another one in the mail to you today.

Sincerely,

Ernest Ndukwe

Ernest Ndukwe
Graduate Student
Department of Resource Development

APPENDIX C

FURTHER DISCUSSION OF THE KEY PHYSICAL AND CHEMICAL CHARACTERISTICS OF PESTICIDE LEACHERS

Canter et al. (1987) descriptively outlined the key physical and chemical characteristics of pesticide leachers, as well as the key soil factors affecting pesticide transport to groundwater. The key physical and chemical characteristics are:

1. Water Solubility: Defined as the propensity for a pesticide to dissolve in water. The higher the water solubility of the pesticide, the greater the amount carried in solution to groundwater. Water solubility greater than 30 ppm has been identified as a "flag" for a possible pesticide "leacher."

2. Soil Adsorption: The propensity of a pesticide to "stick" to soil particles defined as the ratio of the pesticide concentration in soil to the pesticide concentration in water.

3. Volatility: The propensity for a pesticide to disperse into the air. This is primarily a function of the vapor pressures of the chemical and is strongly influenced by climatic and environmental factors, such as temperature and wind speed.

4. Soil Dissipation: This is a measure of the persistence of a pesticide in the soil. It is usually measured as the length of time required for dissipation of one-half the concentration of a pesticide.

Soil dissipation depends on several environmental processes, such as vaporization, as well as on several decomposition processes, such as hydrolysis, photolysis, and microbial transformation. Hydrolysis is the reaction of a chemical with water while photolysis is the breakdown of a chemical from exposure to sun's energy. Microbial transformations occur from the metabolic activities of mircro organisms within the soil.

Bailey et al. (1985) similarly noted four processes believed to influence the rate of decay of pesticides. They are microbial degradation, chemical degradation, photochemical degradation, and volatilization. An additional process to the four processes is organism uptake. It is defined as a condition where the pesticide may be taken up, metabolized, degraded, and excreted by both target and nontarget organisms.

The key soil factors affecting pesticide transport to groundwater as outlined by Canter et al. (1987) are:

1. Clay Content: This refers to the presence of clay minerals. Clay minerals are important because they contribute to cation exchange capacity or the ability of the soil to adsorb positively charged molecules (cations). The positively charged pesticides are, therefore, adsorbed to soil containing negatively charged clay particles. The

fact that clay soils have a high surface area further contributes to adsorption capacity.

2. Organic Matter Content (OMC): Soils with high OMC adsorb pesticides and, therefore, inhibit pesticide movement into groundwater. However, pesticides which are highly adsorbed to organic soil are often applied at higher rates by farmers to compensate for the adsorbed portion. Some of these may later be released into the groundwater. Overall, OMC is important because it affects bioactivity, bioaccumulation, biodegradability, leachability, and volatility of pesticides.

3. Soil Texture: Texture refers to the percent sand, silt, and clay. Leaching occurs more rapidly in coarse or light-textured sandy soils than in fine or heavy textured clayed soils.

4. Soil Structure: Structure is important and it refers to how soil grains are grouped together into large aggregates, such as platy, prismatic, blocky, or granular. Structure is affected by texture and organic matter content.

5. Porosity: This is a function of total pore space, pore size, and pore size distribution. It is determined by soil texture, structure, and particle shape. Pesticide transport is more rapid through porous soils.

6. Soil Moisture: Refers to the presence of water in the soil which is important because it ultimately

transports pesticides that are not adsorbed into the water table below. Capillary action can bring about upward movement of water. In addition, upward movement of water can result from evapotranspiration in which water in the soil is lost to the air.

7. Depth to Groundwater: The distance a pesticide must travel through the soil to reach groundwater is a vital factor in determining whether contamination will occur at a particular site.

In addition to the key physical and chemical characteristics of pesticide leachers and the key soil factors affecting pesticide transport to groundwater, Canter et al. (1987) also noted the key application methods and conditions that affect pesticide transport to groundwater. The methods and conditions are:

1. Local Climatic Conditions: The degree of pesticide leaching at a particular site depends on the amount of local rainfall. Additionally, the temperature of the soil and surrounding air at a site affects pesticides' transport and degradation.

2. Rate of Application: A critical factor in groundwater contamination is how much and how often a pesticide is applied to the soil.

3. Timing of Application: Depending on local environmental conditions, temperature and rainfall, the time of application of a pesticide matters.

4. <u>Method of Application</u>: Aerial spraying, topsoil application (granular, dust, or liquid formulations), soil injection, soil incorporation and chemigation are forms of pesticide application. Soil injection and incorporation are generally considered to pose the greatest likelihood for groundwater contamination. Chemigation, which is the application of pesticides through irrigation, can also be a significant source of groundwater contamination, especially when an irrigation pump shuts down due to mechanical or electrical failure while the pesticide-adding equipment continues to operate. Such a malfunction can cause a backflow of pesticides into the well or cause highly concentrated pesticide levels to be applied to a field.

5. <u>Irrigation Practices</u>: These practices increase the soil moisture content and flow through the soil, raising the potential for chemical leaching. However, irrigation can decrease the amount of volatilization of some pesticides from the soil. Excess irrigation can carry pesticides down the well casings of abandoned or poorly constructed wells, directly injecting contaminants into the aquifer. The use of drainage tiles can also lead to direct input of pesticides into groundwater regardless of their leaching potential.

6. <u>Cultivation Practices</u>: Conservation tillage and no-till practices which curtail soil erosion and

pollutant runoff into streams increases water infiltration and hence the potential for pesticides leaching into the groundwater. In addition, conservation practices require increased herbicide use which may leach.

7. Spillage/Disposal: A high potential for groundwater contamination can result from spillage and disposal due to high concentrations of pesticides in the soil which can overwhelm normal decomposition processes and soil adsorption capacity.

Spillage can be a common problem where pesticide mixing and loading occurs. In addition, handling of unwanted pesticides and empty containers, as well as rinse water from the cleaning of spray equipment may also pose problems which can lead to leaching and eventual contamination of groundwater.

Formulations of Herbicides

How a herbicide performs depends a great deal on the formulation in addition to other factors, such as clay content, organic matter content, texture, porosity, rate of application, and timing of application.

There are two closely-related definitions of formulation:

1. The formulation is the final physical condition in which a herbicide is sold for use (Ware, 1983). Similarly, it is defined as a herbicide

preparation supplied by the manufacturer for practical use. It (the formulation) includes the active ingredient (actual toxicant) and inert ingredients, such as solvents, diluents, and various adjurants (Ross and Lembi, 1985).

2. Formulation is also defined as the process the manufacturer undergoes in preparing herbicides for practical use (Ross and Lembi, 1985). Through the process, the user is presented with a herbicide in a form that handles conveniently.

Matthews (1979) stated that methods of formulating a pesticide are often dictated by cost criteria rather than whether the active ingredient will be more effective. Furthermore, it was indicated that many pesticides have been marketed, as wettable powders, owing both to high cost of suitable solvents for the active ingredient and to the cheaper handling costs of powders.

Major Types of Herbicide Formulations

Most of the herbicides used are sprayable formulations. They include water soluble liquids (S or SL), water soluble powders (WSP), water emulsifiable concentrates (E or EC), wettable powders (W or WP), water dispersible granules (WDG or DF) and water dispersible liquids (WDL, L, or F).

Granules and pellets are dry formulations used for direct application. They comprise a smaller proportion of herbicide formulations used.

Characteristics of the Formulations

Water Soluble Liquids (WSL)

These mix completely in water with minimum agitation and require no additional agitation once dissolved. They require wetting agents for maximum activity and most of the formulations contain 2 to 4 lb. of active ingredient.

Water Soluble Powders (SP)

These are dry, finely divided solids that dissolve completely in water. They remain as solutions indefinitely and do not form precipitates. Typical formulations contain 40 to 90% active ingredient.

Wettable Powders (W or WPL)

These are essentially concentrated dusts or finely ground solids containing a wetting agent to facilitate the mixing of the powder with water before spraying. The wetting agent prevents the powder from floating when added to water. Most wettable powders are used as soil treatments, although sometimes they are used on foliage. The formulations normally contain 50 to 80 percent active ingredient.

<u>Water Dispersible Liquids (WDL, L, or F)</u>

These herbicides frequently designated as liquids or flowables, are finely ground solids suspended in a liquid system. The particles are smaller than those of wettable powders. Some agitation is required. The formulations commonly contain 4 pounds of active ingredient per gallon.

<u>Emulsifiable Concentrates (E or EC)</u>

These are oily (nonpolar) liquids containing emulsifiers. They disperse in water to form droplets of oil surrounded by water (emulsions). They require some agitation. Most of the formulations contain 2 to 6 lbs. of active ingredient per gallon. They are soluble in oil.

<u>Water Dispersible Granules (WDG or DF)</u>

These are also called dry flowables and water soluble granules. They are dry formulations of granular dimensions made up of finely ground solids combined with suspending and dispersing agents. They handle better than dispersible liquids and wettable powders because they disperse without clumping and pour cleanly from the container.

Granules (G)

Granules are applied directly from the package to the field without dilution. Dry substances have been utilized as granule components including clay minerals, starch polymers, dry fertilizers, and ground plant residues. Granules are discrete particles generally less than 10 mm^3 in size. They have an advantage over driftable dry formulations or dusts and also have smaller rate of volatilization. However, they require slightly more rainfall to leach into the soil than sprayable formulations do. Granules were first used in the U.S. in the 1950s, but in spite of the tremendous advantage that no mixing is required, its acceptance as a herbicide application method has been slow. This slowness (or drawback) has been attributed to the fact that the equipment required for granule application is more specialized than a sprayer. Additionally, with a smaller range of products available in granules, farmers are reluctant to purchase a machine with limited use (Matthews, 1979).

Pellets (P)

These are dry formulations in discrete particles that are usually larger than 10 mm^3. They are frequently used for spot applications and their herbicide concentrations typically range from 5 to 20%.

Choice of Formulations

Ware (1983) noted that the real test for a pesticide is acceptance by the user. To be accepted, a pesticide must be effective, safe, easy to apply, and relatively economic.

Matthews (1979) stated that formulations have usually been selected on the basis of convenience to the user. For example, farmers who have large tractor-mounted sprayers fitted with hydraulic agitation prefer emulsifiable concentrates which can be poured straight into the tank from the can, particularly as a volume of concentrate is much easier to measure than to weigh out a powder.

In many parts of the world, the less expensive wettable powder used as prepackaged selected weights has reduced the problem of weighing powders on the farm (Matthews, 1979). In developing countries, choice of formulation has often been dictated by the availability of equipment. For example, in the absence of a sprayer, low-percentage-concentration dusts and granules can be hand-applied. However, where labor or specialized equipment is absent, farmers may be reluctant to use granules. In many areas, scarcity of water dictated the use of dusts and granules, although high costs of transportation have favored the use of highly concentrated formulations since they are less bulky (Matthews, 1979).

Since some plants and individual varieties are susceptible to certain solvents and other ingredients, choice of formulation may be determined by phototoxicity. Phototoxic effects may be caused by chemical burning or by subsequent effects on plant growth (Matthews, 1979). Finally, Matthews (1979) concluded that the choice of formulation is decided by what is readily available and the price.

Herbicide Classification and Mode of Action

There are several ways to classify herbicides. Ross and Lembi (1985) identified eight classifications and declared that herbicide categorization is a matter of convenience based largely on those aspects the describer wants to emphasize.

Five classifications adapted from Ross and Lembi (1985) of herbicides will be addressed. These are classifications based on:

1. Degree of response differences among plant species. In this category, a herbicide is classified as selective and nonselective. A selective herbicide is a chemical that is more toxic to some plant species than to others. Nonselective herbicides are toxic to all species present.

2. Classification based on the Coverage of the Target Area. This category refers to broadcast treatment,

band treatment, and spot treatment. Broadcast treatments comprise of application over the entire field or area. Band treatments describe a somewhat restricted application such as on a row rather than the entire field. Spot treatment refers to application to localized areas, such as on individual plants or weeds.

3. <u>Classification Based in Relation to Crop and Weed Germination and Development</u>: Three important categories in this category are preplant, pre-emergence, and post-emergence herbicides. Preplant herbicides are applied to the soil surface before the seeds are planted. Pre-emergence herbicides are applied before the crop or a particular weed emerges. Post-emergence herbicides are applied after the emergence of the crop or a specific weed.

4. <u>Classification Based on Methods of Soil Application</u>: In this category are herbicides that may be surface applied, incorporated (or mixed into the soil) layered, or injected.

5. <u>Classification Based on Herbicide Movement on or in Plants</u>. Herbicides can also be grouped according to their movement on or in the plant. This category includes:

a. Herbicides that show little or no movement in the plant. These are known as contact herbicides when applied to foliage. An example is paraquat which kills the part of the plant it encounters.

b. Apoplastic (xylem) only movement which move in the system of the plant that conducts water and nutrients

c. Symplastic (phloem) only movement which moves in the symplast with the sugars into the points of active growth or food storage.

Matthews (1979) suggested that "grouping of pesticides according to their mode of action is sometimes of more practical importance than a classification based on chemical structure, since it may affect selection of an application technique."

For a herbicide, the mode of action refers to how the herbicide affects a plant or how it does what it does. Ross and Lembi (1985) identified seven categories, including auxin type growth regulators, photosynthetic inhibitors (where the chloroplast is the site of action), disruption of cell permeability, disruptors of mitosis, seedling root or shoot inhibitors, general metabolic inhibitors, and pigment inhibitors.

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