An Assessment of the COFARM Computer Program to Compare Tillage Practices in the Somerset District of Manitoba

by

Andrew T. C. Wong

A Practicum Submitted in
Partial Fulfillment of the
Requirements for the Degree
Master of Natural Resources Management

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ABSTRACT

To reduce the effects of soil erosion, conservation tillage practices have been recommended across North America. Adoption of conservation practices partly depends upon the knowledge of the effects of soil erosion and crop yield resulting from various tillage practices. A computer program with the capability of simulating effects of tillage practices and generating site-specific recommendations will assist farmers to implement conservation practices.

This study assessed the feasibility of using an interactive data-base computer program (COFARM) for Manitoba conditions. COFARM was used to store and analyze field data collected from silage corn growers in the Somerset District of Manitoba. Erosion and crop yields under five tillage systems were simulated by COFARM. Since the simulation models were developed for U.S. conditions, the simulated results on soil loss and crop yields were found to be invalid for Manitoba conditions.

The possibility of modifying the COFARM program was assessed. The strong coupling and weak cohesion of the program structure create great difficulties in modifying COFARM. The amount of time and resources required for modification warrants a similar program be developed. A new program (MANFARM) is proposed to be constructed specifically for Manitoba conditions.

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Chapter I

INTRODUCTION

1.1 PREAMBLE

The importance of agriculture might not be realized by city dwellers whose activities mainly centre in an urban environment. In fact, agribusiness or agricultural related activities in Canada generate 40% of the gross domestic product, over $20 billion cash receipts annually and about 10% export earnings (The Senate of Canada 1984). Agriculture is also important to Manitoba with it's crop production amounting to 7.09 million tonnes (296 million bushels), which is 18.64% of Canada's production (MDA 1984). In order to maintain this productive output, the quality of the soil must be maintained at a fertile level. The Senate of Canada (1984) expressing government's concern on soil erosion suggests that erosion of one centimeter (one inch) of soil can reduce wheat yields by 40 to 90 kg/ha (1.5 to 3.4 bushels per acre). It further estimates that soil degradation is already costing more than $1.0 billion per year of Canadian farmers' income. In spite of this situation, conventional farming practices that induce soil erosion are still being employed in some areas. This phenomenon may partly be due to the lack of knowledge of the effects and consequences of such practices, and of the technique of conservation practices.

1.2 BACKGROUND

Conservation tillage is widely advocated, especially in the U.S., as a farming technique which would prevent soil erosion, maintain desirable soil structure, retain soil moisture, reduce soil compaction, and conserve organic matter (Phillips and Young, Jr. 1973).

However, the adoption of conservation tillage in Manitoba is comparatively slow. According to the Manitoba Department of Agriculture (1983), there were about 598,000 ha (871,000 ac) of improved farm land annually in summer fallow. This land could be utilized more productively through conservation tillage.

Due to the diversity of soil types, seed sizes and management histories, a sound management decision for individual fields may be difficult for farmers to make. Although there are studies on conservation tillage in Manitoba, they may not be readily accessible or applicable to individual farmer's specific field conditions. Agriculture extension workers may also require great deal of time to gather and synthesize scientific articles and reports for specific management recommendations.

A new computer program - "Coordinated Farm And Research Management (COFARM) Data System for Soils and Crops" has been developed by the United States Department of Agriculture in conjunction with University of Minnesota (Shaffer et al. 1984). It has been designed to collect and store information which could generate management recommendations. Existing soil-crop simulation models access the data from COFARM and management recommendations are generated. Recommendations would be based on soil types, crop and management histories for the specific site. Thus farmers and extension workers may be able to utilize this system in assisting decision making. In addition, researchers may use the information to further develop management options ensuring optimal productivity with these conservation practices (Figure 1.1).

A SUMMARY OF THE UTILIZATION OF - "COFARM"

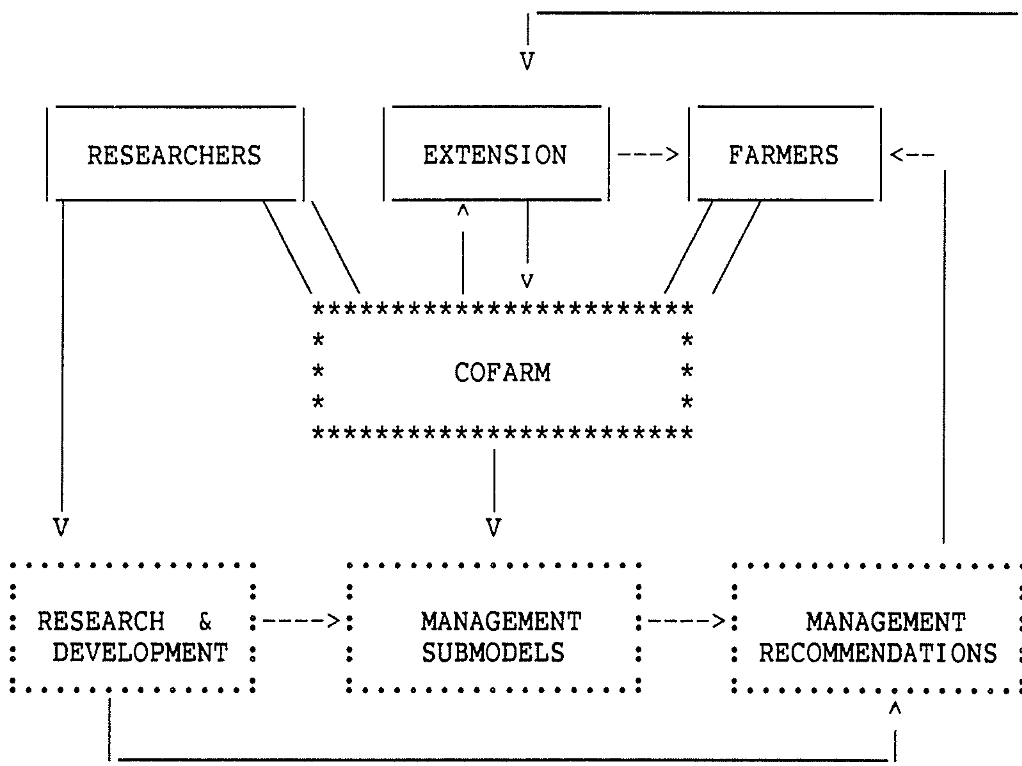

Figure 1.1: Advantages of the COFARM data base computer program.

1.3 PROBLEM STATEMENT

Before a farming practice can be implemented, farmers have to know the advantages and disadvantages, and whether they can implement the practice efficiently. Nowak and Korsching (1985) emphasized that "adoption involves more than the farmer pulling a new tillage implement off a dealer's lot or loading a new herbicide into the back of the pickup. It also involves the farmer having the technical skills to use the technology correctly." In a Western Canadian study, Johnson (1977) also strongly urged: "development of site-specific and environmental-specific recommendations, either synthesized from current and ongoing research data, or developed from improved systems analysis research, is a very definite need."

The Manitoba Department of Agriculture has expressed the need to document the Manitoba situation through quantitative computer analysis (COFARM and other submodels) including tillage effects on productivity and soil status variables. The Manitoba Department of Agriculture Annual Report of 1983 also indicates that farmers are interested in learning about conservation tillage such as zero-tillage, including the feasibility of winter wheat production, and soil conservation benefits. The data base system COFARM will organize and store farm history, individual field characteristics and generate site-specific recommendations. Thus, extension workers can help farmers to adopt conservation practices with confidence and accuracy.

1.4 OBJECTIVES

The purpose of this study was to assess the technical feasibility of using a data base computer program (COFARM), designed and used in the U.S., to compare effects of conservation and moldboard plow tillage practices for individual farmers in a specific area of Manitoba. Specifically, the following objectives were studied:

1. To compile necessary data from corn growers in the study area for the data base program;
2. By means of COFARM, to compare the effects on soil erosion and corn yield under conservation tillage and moldboard plow;
3. To determine the applicability of COFARM for Manitoba corn growers;
4. To examine and suggest modifications that would be necessary to enable COFARM to be used for other Manitoba crops and farming situations.

1.5 DELIMITATIONS

This study made no attempt to compare the economic benefits between conservation and moldboard plow tillage systems. Nor did this study assess the economic feasibility of implementing the COFARM program in Manitoba.

This study also did not compare all effects of chemical and physical properties of soil under both tillage operations. It is generally recognized by soil scientists that conservation tillage maintains desirable soil conditions and decreases soil erosion.

Chapter II

CONSERVATION TILLAGE

2.1 INTRODUCTION

Conservation tillage has drawn the attention of many researchers in recent years. Since conservation tillage includes many farming practices that would conserve soil, it is difficult to define conservation tillage precisely.

2.2 DEFINITION OF CONSERVATION TILLAGE

Many definitions are available from different sources for conservation tillage. The following are some examples:

1. Conservation tillage is any reduced tillage practice that helps to conserve soil and/or water (Donahue et al. 1983);
2. Conservation tillage: any tillage sequence that reduces loss of soil or water relative to conventional tillage (moldboard plow); often a form of non-inversion tillage that retains protective amounts of residue mulch in the surface (SCSA 1982);
3. Conservation tillage is a system of tillage that leaves protective amounts of crop residue on the soil surface during periods when growing crops do not provide cover and when erosive rains, runoff, snowmelt, or winds normally occur. The major types of conservation tillage systems are no-till, strip tillage or

till planting, stubble mulching, and chemical fallow or ecofallow (Darby 1985).

The common elements of these definitions are the management of crop residue as protective cover and reduced tillage operations to minimize soil disturbance. Needless to say, all these definitions indicate the primary purpose of conservation tillage - that is to conserve soil or prevent soil erosion. The principle difference between conservation tillage and conventional tillage is the use of the moldboard plow (Crosson 1981). Since the moldboard plow buries most crop residue and disturbs or inverts the soil more than conservation tillage systems, it is generally referred to as conventional tillage. In this study, chisel plow, no-till, ridge tillage and disc are all considered to be conservation tillage whereas moldboard plow is conventional tillage.

2.3 EFFECTS OF CONSERVATION TILLAGE

There is a great deal of research that has been conducted to examine the various effects of conservation tillage on soil properties and crop yields. This review will only examine some of these aspects that are pertinent to prevention of soil erosion and its effect on crop yields.

2.3.1 Soil Erosion

In many instances, conservation tillage has been demonstrated as an effective means of preventing wind and water erosion. It has been estimated that, after a high intensity simulated rainstorm, the no-till systems of conservation tillage reduced soil loss by 95 percent compared with moldboard plow (Griffith et al. 1977). Other studies indicate that conservation tillage reduces erosion 50 to 90 percent compared with moldboard plow (Harrold et al. 1970; Fenster 1977; Reicosky et al. 1977; Siemens and Oschwald 1978; Phillips et al. 1980). Amemiya (1977) shows that various forms of conservation tillage reduce erosion 30 to 90 percent compared with moldboard plow. The general consensus is that reduction of soil loss in conservation tillage is due to surface residue.

The role of topsoil is to maintain sustainable crop yield. Once the topsoil has eroded, it will result in yield reduction. In some instances, however, the effect on yield caused by soil erosion may not be readily observed. This is dependent on the thickness of the surface soil, the quality of the subsoil, and the rate of erosion. It is essential to examine short-term as well as long-term effects on yield when comparing conservation and moldboard plow tillage practices.

There are a number of research reports indicating the deleterious effects on soil due to moldboard plow methods (Bauder et al. 1981; Powers and Skidmore 1984; Unger 1984; Van Doran, Jr. et al. 1984) and others are determining the relationship between the amount of soil eroded and the reduction of crop yield (Frye et al. 1982; Becher et al. 1985; Kenyon and Shaykewich 1987; Morrison Ives and Shaykewich 1987). Farmers may not readily comprehend the magnitude of yield reduction in relation to a given amount of soil loss on their own fields. Although there are studies conducted to measure the effect of soil erosion on crop yields, those studies examine factors such as soil formation (Langdale et al. 1979), application of N fertilizer (Engelstad and

Shrader 1961; Engelstad et al. 1961), and salinization (The Senate of Canada 1984) rather than conservation practices (Becher et al. 1985). This probably is one of the contributing factors that conservation practices are not being readily adopted.

Becher et al. (1985) found that under the loess soil, corn yield reduction of 3.7 t/ha could occur within 10 years if there was no erosion control. Crosson (1981) hypothesized the long-term yield relationships in terms of soil erosion and moldboard plow tillage. From his hypothetical graph (Figure 2.1), crop yield under conservation

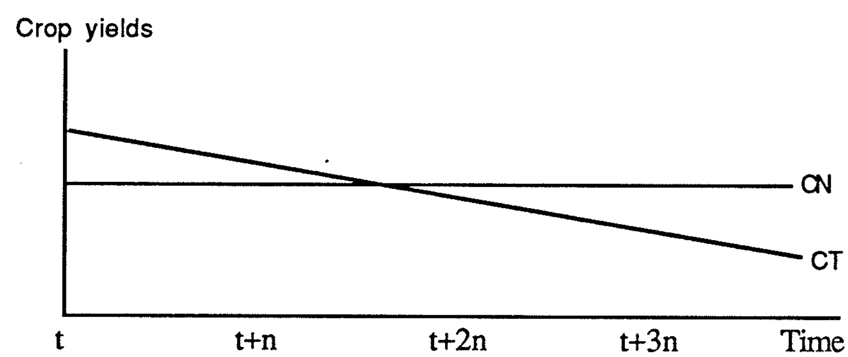

Figure 2.1: A comparison of hypothetical long-term yield under two tillage systems (Adapted from Crosson 1981).

tillage is probably lower in the initial stage. He explained that it maintains the same level on a long-term basis, provided that fertilizer and soil loss have been adjusted at a tolerable level. He also believed that crop yields under moldboard plow are higher than conservation tillage at the initial stage, but due to the rapid rate of soil loss crop yield drops below that of conservation tillage after a short period of time. This reduction in yield is continuous and it cannot be rectified by fertilizer input. Such loss is often irreversible (Becher et al. 1985). In the study on the effects of simulated soil erosion on wheat yields, Morrison Ives and Shaykewich (1987) concluded that a portion of the yield decreases due to erosion was overcome by a large additions of fertilizer but the original productivity of the soil could not be restored.

Further research with regard to the actual amount of yield reduction in relation to the amount of soil loss under conservation and moldboard plow tillage is necessary. On a long term basis, conservation tillage systems reduce soil loss thereby yield reduction caused by soil erosion should be less than that of moldboard plow system. A mathematical model, the Erosion Productivity Impact Calculator model, for determining relationships between soil erosion and soil productivity, is in its final testing in the U. S. (Renard and Follett 1985).

2.3.2 Soil Moisture and Temperature

It is generally recognized that soil moisture is higher and soil temperature in spring is lower under conservation tillage (Crosson 1981; Gauer et al. 1982; Busscher and Sojka 1985; Lonkerd and Dao 1985; NeSmith et al. 1985; Utomo et al. 1985). Therefore, the moisture conserving effect of conservation tillage is definitely welcome by those farmers in an area prone to moisture deficit. On the other hand, an area with poorly drained soil poses a problem to conservation tillage.

Generally, yield on poorly drained soils with conservation tillage is lower. Nevertheless, studies indicate that excess moisture under conservation tillage can be rectified (Phillips and Young 1973; Triplett and Van Doran 1977). This probably explains why under conservation tillage yields have been highly variable.

Soil temperature is another important factor should be considered. Sufficiently high temperature is essential to seed germination and emergence, nutrient uptake and growth. Willis and Amemiya (1973) found that low soil temperatures inhibits availability and uptake of nutrients, particularly phosphorus and nitrogen. They also suggest that low soil temperature induces slow seed emergence, seed germination and subsequent early growth.

As mentioned earlier, soil temperature is lower under conservation tillage than under moldboard plow tillage. However, Gauer et al. (1982) found that if straw was removed by raking, soil temperature of zero-tilled fields were warmer than moldboard plow tilled fields. Crosson (1981) suggests soil temperatures that are lower with conservation tillage on poorly drained soils are due to the greater moisture content of these soils and the high heat capacity of water. Carter and Rennie (1985) also indicate that the differences in maximum and minimum soil temperature, accumulative heat sums and thermal diffusivity are related to variations of soil moisture, in addition to surface crop residues and crop canopy. Their general maximum soil temperatures are 1-5 ^{0}C lower with zero tillage than moldboard plow tillage during the first 30 days of crop growth for spring wheat in a semi-arid region of Saskatchewan. Ironically, their study shows that "soil temperature differences are not associated with differences in yields of spring or winter wheat." Crosson (1981) comes to a similar conclusion but added that the delay in spring planting due to lower soil temperature makes conservation tillage unsuitable to crops requiring a full season for growth.

2.3.3 Winter Wheat Production

Winter wheat production is another cropping system compatible with soil conservation. Studies show that zero-tillage provides a favorable environment for survival of winter wheat (Grant et al. 1984). Under zero tillage, standing stubble is left on the surface of the field and serves as an insulation material. Winter soil temperature, thus, is higher than that of moldboard plow tillage. Table 2.1 shows the higher percentage of winter survival under zero tillage than that under moldboard plow (Grant et al. 1984). This study also suggests that "differences in P response between zero and conventionally tilled (moldboard plow) treatments may therefore reflect increased damage to conventionally tilled wheat due to the lower soil temperatures resulting from a lack of insulating snow cover."

2.3.4 Fertilizer Requirements

It is difficult to make judgements regarding fertilizer requirements under conservation and moldboard plow tillage. As mentioned earlier, there are long-term effects of soil loss or nutrient loss due to erosion. On a long-term basis, moldboard plow with no control of soil loss may probably require a larger amount of fertilizer. Especially, after a long period of time under moldboard plow tillage, fertilizer

TABLE 2.1

Winter wheat survival under zero and moldboard plow

		1980 - 1981	
Nitrogen (kg/ha)	Phosphorus (kg/ha)	Zero-tilled winter survival (%)	Conventionally tilled winter survival (%)
0	0	74.5	35.4
60	0	69.9	25.7
120	0	59.7	26.0
0	8.7	75.0	42.7
60	8.7	76.6	44.0
120	8.7	69.5	40.0
0	21.7	70.8	51.2
60	21.7	78.6	49.3
120	21.7	74.1	39.0

Source: Grant et al. 1984.

response might decrease to the point where a large amount of fertilizer would be required to increase only a little yield. On the other hand, conservation tillage with a slower rate of soil loss, yield response would be higher than the moldboard plow tillage after certain periods of time. The fertilizer requirement, thus, is probably comparatively lower under conservation in the long-run. This is merely speculation which requires much research to substantiate it, though. Studies, however, indicate that the N fertilizer requirement under conservation tillage is higher than that of moldboard plow tillage. Legg et al (1979) found that a higher N fertilizer was required under minimum tillage than moldboard plow in order to achieve the maximum silage corn yield. The study of Thomas et al (1973) suggested that a higher N fertilizer was recommended for no-tillage corn than for moldboard plow tilled corn on the same land in Kentucky. In a recent 4-year study, Meisinger et al (1985) concluded that "corn grown with minimum tillage required about 68 Kg more N fertilizer per hectare than moldboard plow tillage corn due to a greater crop N requirement and a lower uptake of soil nitrogen". The lower soil temperature and higher soil moisture of conservation tillage is believed to impede the mineralization of nitrogen and promote denitrification (Amemiya 1977; Fenster 1977; Griffith et al. 1977; Phillips et al. 1980).

2.3.5 Nitrate Leaching

Crosson (1981) believes that there is no convincing evidence that indicates a difference in delivery of nitrates and available phosphorus to water bodies under conservation tillage from that under moldboard plow tillage. Phillips et al. (1980), however, show that nitrates leach more readily on zero-till plots than on moldboard plow tilled plots. In addition, studies demonstrate that conservation tillage contributes less of dissolved concentrations of N in surface runoff from soil than moldboard plow tillage (Romkens 1973; McDowell and McGregor 1980 and 1984). Alberts and Spomer (1985) suggest that possible reasons for higher nitrate leaching under conservation tillage "include incomplete incorporation of surface-applied fertilizer, direct-dissolved nutrient contributions from decaying plant residues, and higher dissolved N and P concentrations in the surface soil because of residue accumulation and decomposition." To arrest the unacceptable high level of leaching of NO_3-N, they offer a solution with the two following approaches:

1. "...to match N fertilizer applications more closely to plant requirements or to develop stabilizers that will release the N slowly as the growing crop needs it.
2. to reduce the amount of water that percolates below the root zone."

Studies are being conducted on the use of cover crop and living mulches to reduce N fertilizer requirements, herbicide application and soil erosion (Alberts and Spomer 1985).

Chapter III

APPROACH

3.1 DESCRIPTION OF STUDY AREA

The Somerset district was suggested as the study area by the Manitoba Department of Agriculture. The study area is located southwest of Winnipeg within the Pembina Hills wooded area in the Province of Manitoba (Figure 3.1). According to the Reconnaissance Soil Survey of South-Central Manitoba (Ellis and Shafers 1943), the two major soils found in the area are the Pembina Clay Loam and Altamont Clay Loam. Due to the rolling and hilly topography in some regions, water and wind erosion have become serious problems on the cultivated fields. Conservation practices, thus, should be implemented to ensure future production.

The adoption of conservation tillage in this area is believed to be slow. Local experienced farmers and agriculture representatives in this area indicate that the problem encountered by local farmers using conservation tillage is an excessive amount of crop residue. Some farmers have tried minimum tillage, but they have a problem with crop residue management. In some situations, they resort to burning the excessive crop residue. Consequently, this leads other farmers to believe that minimum tillage is almost impossible in this area. A computer program providing accurate information that assissts in making site-specific decisions would be helpful to farmers in their consideration to adopt conservation tillage.

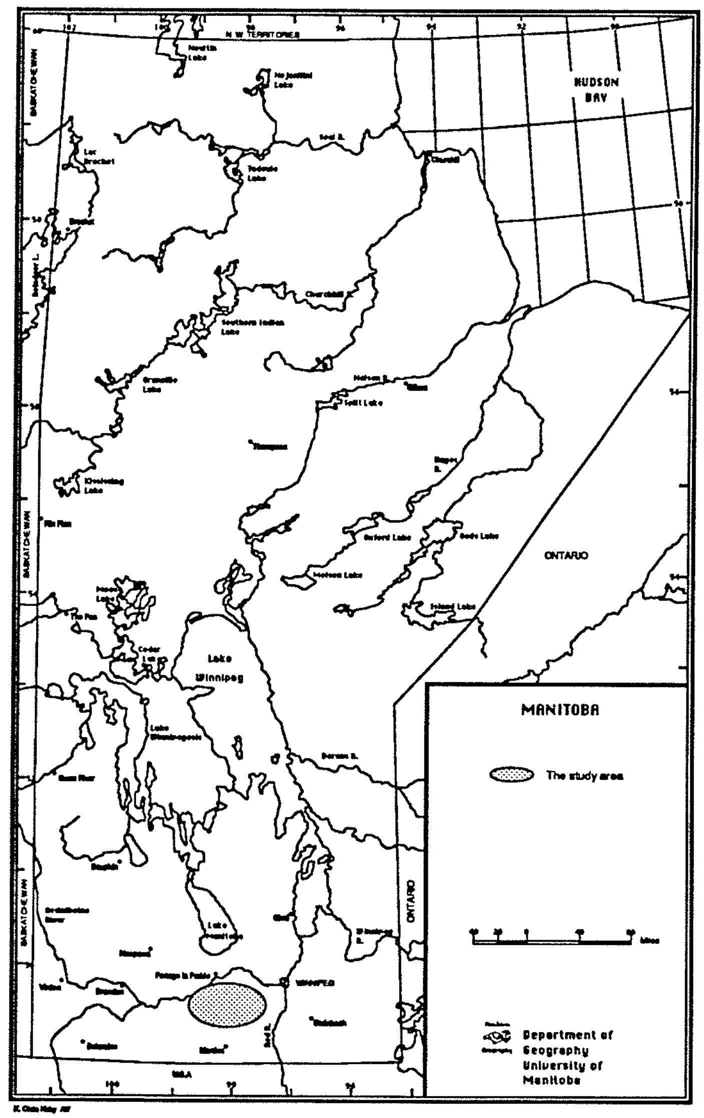

Figure 3.1: The study area - Somerset, Manitoba.

3.2 COMPUTER SIMULATION MODELS

Since much of the scientific information is scattered or unpublished and a diversity of variables affect cropping patterns, a computer program which organizes and synthesizes data and generates management options is essential.

A computer data base system with simulation submodels was developed in the United States called the Coordinated Farm and Research Management (COFARM) model (Shaffer et al. 1984). This system coordinates "information on soils, management history, and crop yields into a comprehensive data system covering a range of soil types, crops, management techniques, and climatic regimes" needed by farmers and researchers. Simulation models can use these data to generate site-specific management recommendations for individual farmers, fields, soils and crops. This model, however, does not perform economic analyses.

3.3 THE COFARM COMPUTER MODEL

This computer system consists of two main modules - a data management package and a simulation submodel. The data management module organizes the data from each farm. Individuals may create, update and access their data file for each field of their farm. This module also supplies the U.S. SCS SOILS-5 national soil data base for matching farm data. The simulation module of COFARM is used to generate management options in the areas of nitrogen fertilizer, tillage and crop residue management; and predictions of soil erosion, nitrate leaching, and crop yields. One of the advantages of this model is that it is quite flexible allowing different data input. The simulation models, thus, access those data used for recommendations and predictions without being supplied with pre-existing information limiting the analysis to certain field or climatic regimes.

It is not only "user friendly", but the outputs are also in layman's form. Farmers are able to comprehend the simulated yield loss associated with a given tillage practice, for example, with moldboard plow (Table 3.1). A farmer would want to know the effects of these systems on his

TABLE 3.1

An example of output from COFARM showing yield loss summary for moldboard plow

-----Yield Loss Summary-----

			Yield Loss Summary in bu/acre					
Soil Type	% of Field	Pro- jected yield	Loss from lack Nit	Loss from plt date	Loss from plt pop	Loss from temp a&s	Loss from till prac	Loss from dro- ught
Hooptn (SL)	50	68	0	1	0	19	21	111
Kasson (SiL)	20	159	0	1	0	10	2	30
Maxfd (SiCL)	30	127	36	1	0	12	0	24
Combined Soils	100	104	11	1	0	15	11	69

Source: Shaffer and Johnson 1985.

land. COFARM generates an "environmental section" output displaying to the farmer individual fields, the amount of erosion, and NO_3-N on each

TABLE 3.2

An example of output from COFARM showing environmental section for given soil types and management

-----Environmental Section-----

Given your soil types and management conditions, long term soil erosion and NO_3-N leaching this year as follows:

Soil type	% of field	Soil erosion (tons/ac/yr)	NO_3-N leached (lbs/ac/yr)
Hoopeston (SL)	50	4.3	0
Kasson (SiL)	20	30.1	2
Maxfield (SiCL)	30	0.0	1
Combined Soils	100	8.2	1

Source: Shaffer and Johnson 1985.

soil type (Table 3.2). Furthermore, the advisory section may suggest what actions he/she may have to take due to the climatic conditions (Table 3.3). The user can also compare different yields under different tillage systems (Table 3.4). In addition, under the environmental section for this menu, the user is able to readily observe the different impacts in terms of soil loss and NO_3-N leached under each tillage system (Table 3.5).

TABLE 3.3

An example of output from COFARM showing advisory section of management recommendation output

-----Advisory Section-----

The recent rains and below normal temperatures may delay corn development slightly. You may want to postpone your harvest.

Source: Shaffer and Johnson 1985.

TABLE 3.4

Partial display of an example of output from COFARM showing sensitivity table for different practices

-----Sensitivity Table-----

Projected yields for wet, average, and dry years with various tillage practices

Wet year Soil type	% of field	Corn Yield (bu/ac) Tillage Practice MP	 CP	 NT	 RTL	 DISC
Hoopeston (SL)	50	94	119	115	118	111
Kasson (SiL)	20	156	159	153	156	159
Maxfield (SiCL)	30	84	88	80	84	88
Combined soils	100	104	118	112	115	114

MP - Moldboard plow CP - Chisel plow
NT - No-till RTL - Ridge tillage

Source: Saffer and Johnson 1985.

TABLE 3.5

Partial display of an example of output from COFARM showing the environmental section

-----Environmental Section-----

Given your soil types and management conditions, long term soil erosion and NO_3-N leaching this year are as follows:

Soil type	% of	Tillage Practice	Soil erosion (tons/ac/yr)	NO_3-N leached (lbs/ac/yr)
Hooptn (SL)	50			
		Conventional	4.3	0
		Chisel plow	1.4	0
		No till	.8	0
		Ridge till	.8	0
		Disc plow	1.4	0

Source: Shaffer and Johnson 1985.

There are five simulation commands, 16 management options and five types of recommendations from the appropriate menu (Table 3.6). A user may, therefore, choose any of these menus to generate management recommendations which generally consist of a yield loss summary (Table 3.1), an environmental section (Table 3.2), and an advisory section (Table 3.3). Additional comments are generated when applicable.

As a result, farmers gain information to allow for better management decisions. They are able to visualize the short- and long-term aspects of different practices.

TABLE 3.6

A list of three menus compose different options

Current Management Options Menu

1. WHICH SOILS YOU WANT RECOMMENDATIONS FOR
2. TYPE OF CROP (INCLUDES MATURITY RATING)
3. PLANTING DATE
4. PLANT POPULATION
5. SOIL MOISTURE AT PLANTING
6. COMPUTER'S OR YOUR ESTIMATES OF PRECIPITATION
7. COMPUTER'S OR YOUR ESTIMATES OF TEMPERATURES
8. SOIL TEST NITROGEN
9. PROPOSED (OR PAST) FERTILIZER PRACTICE
10. PROPOSED (OR PAST) TILLAGE PRACTICE
11. PROPOSED (OR PAST) RESIDUE MANAGEMENT PRACTICE
12. LOCATION CODE
13. COMPLETELY NEW RECOMMENDATION
14. LIST CURRENT VALUES FOR MANAGEMENT VARIABLES
15. RETURN TO SIMULATION COMMAND MENU

Recommendations Menu

1. TILLAGE RECOMMENDATION
2. N FERTILIZER RECOMMENDATION
3. CROP RESIDUE MANAGEMENT RECOMMENDATION
4. PLANTING DATE RECOMMENDATION
5. PROJECTED OR "POST-MORTEM" (PAST SEASON) ANALYSIS

Simulation Command Menu

1. COMPUTER MANAGEMENT RECOMMENDATION
2. LIST THIS SEASON'S MANAGEMENT SETTINGS
3. CHANGE THIS SEASON'S MANAGEMENT SETTINGS
4. CHANGE RECOMMENDATION REQUEST
5. RETURN TO PAST DATA MANAGEMENT MENU

Source: Shaffer and Johnson 1985.

3.4 PROCEDURES

The COFARM computer program consists of the U.S. SCS soil data base for counties within the Cornbelt region. Manitoba soil types and variable values, however, were entered for simulations.

3.4.1 Data Collection

A questionnaire for collecting appropriate data for the COFARM computer program was designed and provided by the University of Minnesota (see Appendix G). It was used in collecting adequate data such as soil properties, crop history, tillage history, fertilizer history, residue and miscellaneous problems for each field. This helped to compile data which can be stored in COFARM as a data base and utilized for simulation analyses.

For this study, 15 to 20 corn growers were needed for the study sample. These growers were determined in consultation with Manitoba Department of Agriculture specialists.

Due to the design of the questionnaire, personal interviews with the farmers were necessary. Data collected from farmers was examined before being stored in the COFARM for simulation analyses.

3.4.2 Comparative Assessment

Once the necessary data had been collected and compiled, the output of the existing corn simulation submodel generated from COFARM was used for comparative assessment. There were mainly two dependent variables for each field under varying soil and tillage practices which could be compared, i.e. corn yield and soil erosion. Each field had different soil types - independent variable A. Under different tillage practices - independent variable B - the amount of yield and soil erosion thus varied. Therefore, soil types and tillage practices were the two

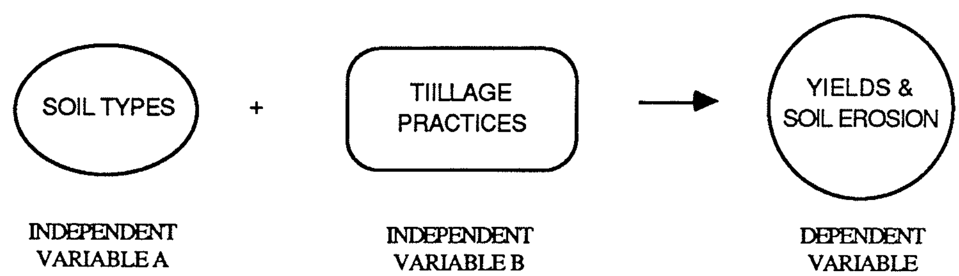

Figure 3.2: Independent and dependent variables used in the study area.

independent variables (Figure 3.2).

One of the two independent variables was kept constant at a given operation. First, soil types were kept constant when comparing effects on yield and erosion under different tillage practices. Secondly, holding tillage practices constant, the amount of yield and soil erosion were compared to the same type of tillage practice for the two soil types. Figure 3.3 summarizes this comparative assessment.

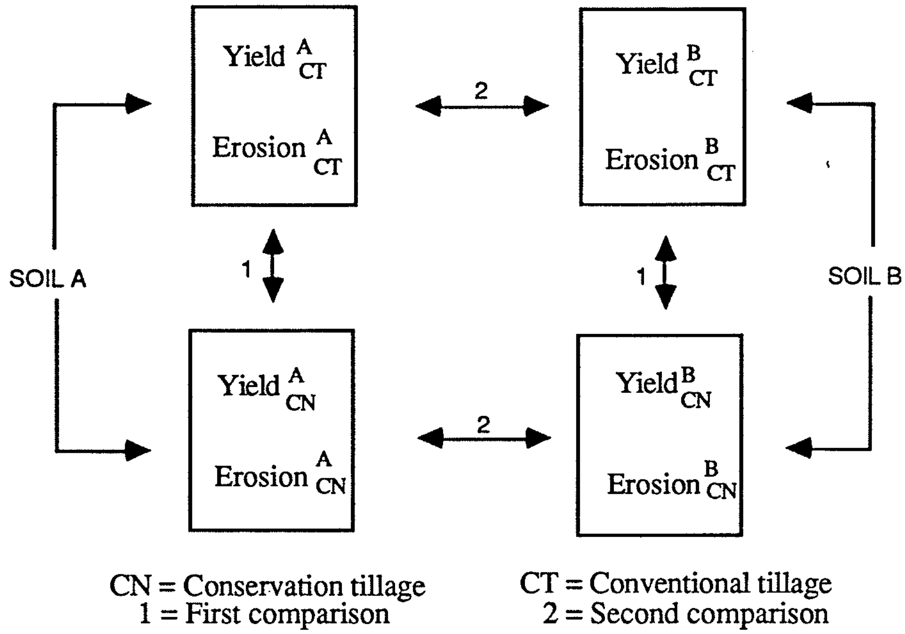

Figure 3.3: Diagramatic explanation of the comparative assessment.

3.4.3 Applicability to Manitoba

The yield and erosion estimates generated by the COFARM submodel were assessed as to their general validity. Since it was impossible to test the actual amount of yield and soil erosion, general trends were observed to test the submodel's prediction. For instance, a more steeply sloped field should have had higher erosion under moldboard plow than under conservation practices.

In addition, the feasibility of replacing or modifying the existing submodel and soil data base needed to be examined in order to assess the possibility of implementing COFARM for other crops and locations in Manitoba.

Chapter IV

RESULTS AND DISCUSSION

4.1 DATA ACQUISITION AND COMPILATION

Due to time and resource constraints, this study was conducted retrospectively. The previous three-year specific farm data were collected by interviewing a number of farmers. They provided their tillage practices, fertilizer applications and crop yields of the former three years mostly from memory. Most of the information, therefore, was approximated.

Of the twenty one farmers contacted in the study area, only twelve farmers were interviewed. There were nineteen fields in total and were all growing silage corn in the 1986 growing season. Unfortunately, no grain corn grower was found in the area.

Fifteen soil series were identified with the assistance of the Canada-Manitoba Soil Survey (Table 4.1). Soil textures ranged from silty clay loam to loamy fine sand with the majority being clay loam. The lowest organic matter content was 2.5% in Stockton fine sandy loam. The highest organic matter content, 8%, was found in 5 soil series. Stockton fine sandy loam and Doblin loamy fine sand have the lowest water holding capacity with 21.3 cm water per 150 cm depth. The highest water holding capacity is 34.0 cm of Firdale silty clay loam.

TABLE 4.1

A summary of characteristics of soil identified in the study area.

Soil Name	Texture	% O.M.[1]	W.H.C.[2] (cm)	Depth to water table	Depth to bedrock	Bulk Density 0-60	Bulk Density 61-150cm	k Factor	Slope (%)	Slope length	Slope direction	Amt. erosion
CROYON	SiCL	8.0	30.5	>2.0 m	------	1.3	1.7	.22	1.5	610 m	SE	N/S[3]
FIRDALE	SiCL	5.1	34.0	>2.0 m	------	1.3	1.3	.22	1.0	701 m	NE	N/S
DANLIN	SiCL	6.5	33.8	1.22 m	------	1.5	1.7	.22	0.5	305 m	SW	N/S
DEZWOOD	CL	6.0	30.5	>2.0 m	------	1.3	1.4	.22	4.0	760 m	NW	N/S
DARLINGFORD	CL	8.0	30.5	>2.0 m	------	1.3	1.4	.22	3.0	490 m	SW	N/S
TIGER HILL	CL	5.6	29.0	>2.0 m	------	1.4	1.5	.22	2.0	760 m	N	N/S
RAMADA	CL	6.5	33.8	>3.0 m	------	1.3	1.3	.22	1.5	610 m	E	N/S
MANITOU	CL	6.0	30.5	>2.0 m	------	1.4	1.4	.22	1.0	760 m	W	N/S
KNUDSON	CL	8.0	30.5	>2.0 m	------	1.4	1.4	.22	1.0	305 m	SW	N/S
HALSTEAD	SiL	5.4	22.4	>2.0 m	------	1.5	1.6	.27	1.5	610 m	SW	N/S
FAIRLAND	SiL	8.0	30.5	>2.0 m	------	1.4	1.4	.26	0.5	215 m	W	N/S
FROSTWICK	L	8.0	30.5	>2.0 m	1.0 m	1.3	1.8	.26	1.0	215 m	SE	N/S
GLENBORO	VFSL	3.4	22.4	>2.0 m	------	1.5	1.6	.30	1.5	915 m	NE	N/S
STOCKTON	FSL	2.5	21.3	>2.0 m	------	1.5	1.6	.16	0.5	760 m	E	N/S
DOBLIN	LFS	6.8	21.3	>2.0 m	------	1.3	1.3	.17	4.0	760 m	NE	MOD.[4]

[1]Organic Matter (top 30.5 cm). [2]Water Holding Capacity to 152 cm depth. [3]None to slight. [4]Moderate.

Source: Mike Langman, Canada-Manitoba Soil Survey. Personal communication. 1986.

Data source and accuracy should be noted. Soil series were identified by data recently acquired from the Canada-Manitoba Soil Survey team working in the study area. Specific physical and chemical properties of the identified soils were taken from the soil survey laboratory findings (Langman 1986). Individual site inspection generated more accurate in situ information pertaining to soil type, textural class, organic matter content, water holding capacity and bulk density.

Another observation during interviews was that the majority of the farmers interviewed had limited knowledge of technical terms commonly used by agronomists. They were not certain of the soil name, textural class and percent organic matter for their fields. Soil properties such as bulk density and water holding capacity were foreign to most participants. Of the twelve farmers interviewed, only four had a soil survey within the past four years.

Data pertaining to tillage practices are shown on Table 4.2. There were nine tillage systems reported in the study area (Table 4.2). All but one (moldboard plow) were considered to be conservation tillage. Field cultivator was the dominant tillage operation used by the farmers (17 fields) in all three years (1983 to 1985). The second most popular tillage system operated in 1985 was chisel plow on 11 fields. The number of fields (7) employed chisel plow was identical to that of moldboard plow in 1983 and 1984.

A pattern of tillage practices from 1983 to 1985 was the decrease in the use of moldboard plow. In both 1983 and 1984, seven fields were

TABLE 4.2

Tillage practices of silage corn growers interviewed in the study area (1983 to 1985)

Tillage Systems[1]	Number of fields			Number of operations			Tillage depth		
	'85	'84	'83	'85	'84	'83	'85	'84	'83
3	**11**	**7**	**7**	**1**	**1**	**1**	**4-6"**	**4-6"**	**4-6"**
4	**1**	**7**	**7**	**1**	**1**	**1**	**5"**	**4-6"**	**4-6"**
5	0	1	1	0	1	1	0	1"	5"
6	7	6	5	1-2	1	1	3-5"	4-6"	4-6"
7	17	17	15	1-4	1-3	1-3	2-6"	2-5"	2-5"
8	2	1	1	1	1	1	2"	2"	2"
9	3	3	3	1-2	1-2	1-2	1-2"	1-2"	1-2"
10	0	1	1	0	2	2	0"	2"	2"
11	1	1	1	1	1	1	2"	2"	2"

[1]Tillage numbers and descriptions are taken from COFARM questionnaires

3 = Chisel plow, or disc then chisel plow
4 = Moldboard plow
6 = Disc, with 22 inch blades
5 = Disc, large plowing type, or offset disc, with large (26 inch) blades
7 = Field cultivator
8 = Springtooth
9 = Drag
10 = Lelly roterra
11 = Soil finisher

tilled by moldboard plow. In 1985, only one field used the moldboard plow. An increase in the use of the chisel plow was also recorded in 1985. This shift implies that corn growers in the study area seem to be adopting the conservation systems. Since moldboard plow leaves only 0-5% surface residue after tillage, whereas 75% is left with the chisel plow and 80% with field cultivator (Hayes and Young 1982), this fulfills one of the objectives of conservation tillage. The number of operations per field and the depth for each of the tillage systems were consistent throughout the three-year (1983-1985) period. It should also be noted that the depth of tillage operation for both moldboard and chisel plow tillage systems were the same.

4.2 TILLAGE EFFECTS ON SOIL EROSION

The analysis generated by COFARM shows the rates of soil erosion under different tillage systems (Appendix B). Figure 4.1 illustrates the average simulated rate of erosion in eighteen fields under five tillage systems. Moldboard plow contributed the highest rate of soil erosion in all fields. Among conservation systems, the average soil loss in all fields under no-till and ridge tillage was lower than chisel plow and disc tillage systems. According to COFARM, the rate of erosion for the chisel plow was consistently the same as disc, and no-till was also consistently identical with ridge tillage. With all fields combined, the average rate of soil erosion in moldboard plow was over two times higher than using the chisel plow and disc, and over 3 times higher than no-till and ridge tillage systems. The order of soil loss simulated by COFARM can be summarized as follow: moldboard plow > chisel plow, disc > no-till, ridge. This pattern conforms with the findings of Hayes and Young (1982). It should be noted that the rate of soil loss simulated by COFARM in this study is overestimated because the rainfall

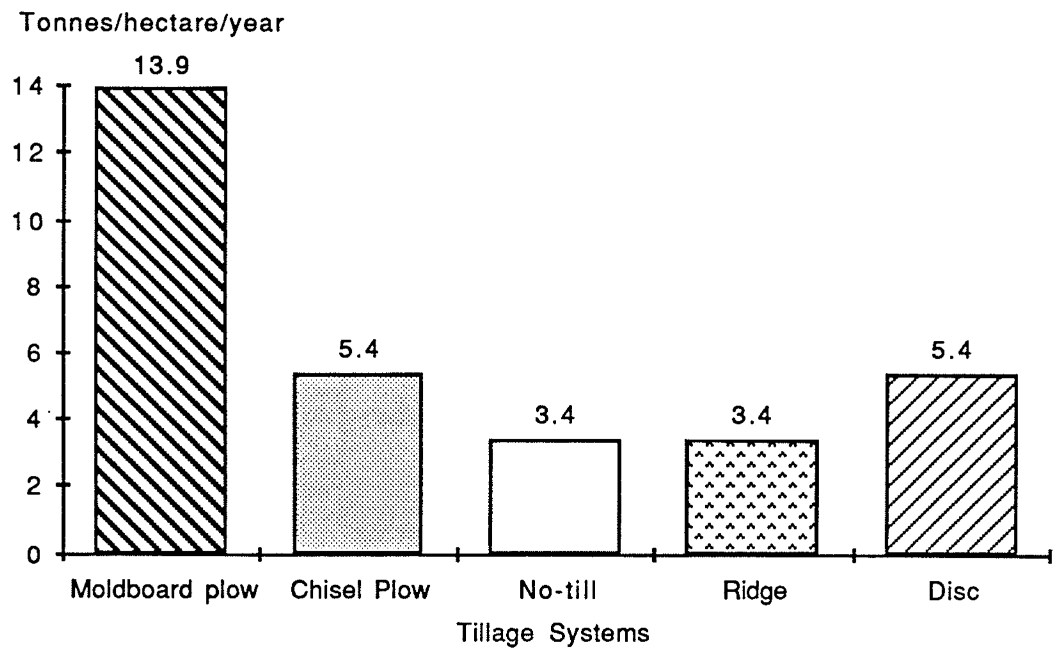

Figure 4.1: Average simulated soil loss under five tillage systems.

data used in the simulation was much higher than observed in the study area in Manitoba.

Since soil texture, organic matter content and slope are different in each field, erosion rate varies from field to field. Moldboard plow, again, contributed the highest average soil loss in all textural classes and no-till and ridge tillage were the lowest (Figure 4.2). The rate of soil erosion is influenced by soil texture. Erosion rate tends to increase with higher silt content and decrease with higher sand and clay content (Langman 1982). The simulated average soil loss in Figure 4.2,

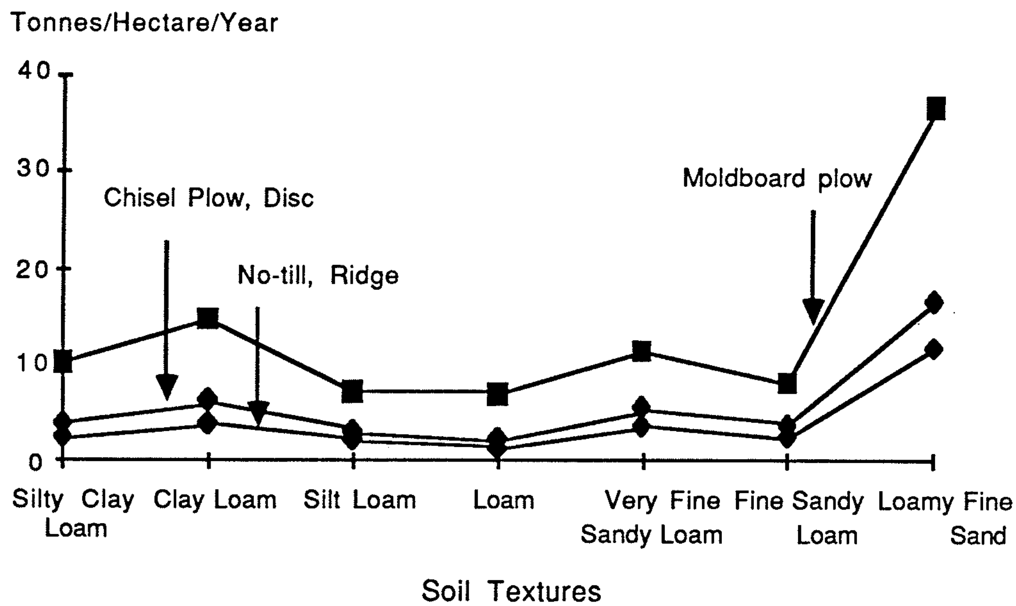

Figure 4.2: Average simulated soil loss under the five tillage systems in different soil textures.

however, does not exhibit this trend. According to Figure 4.2, loamy fine sand had the highest average erosion rate when compared with other textural classes. This could be explained by Figure 4.3 when degree of slope is also taken into consideration. The average soil loss was substantially higher in clay loam with 3 to 5% slope and loamy fine sand with 4% slope. If all textural classes were compared with the similar degree of slope (0 to 2%), average soil loss were quite uniform.

Another important factor for soil erosion is the degree of slope. Figure 4.4 illustrates the average soil loss according to slope classes

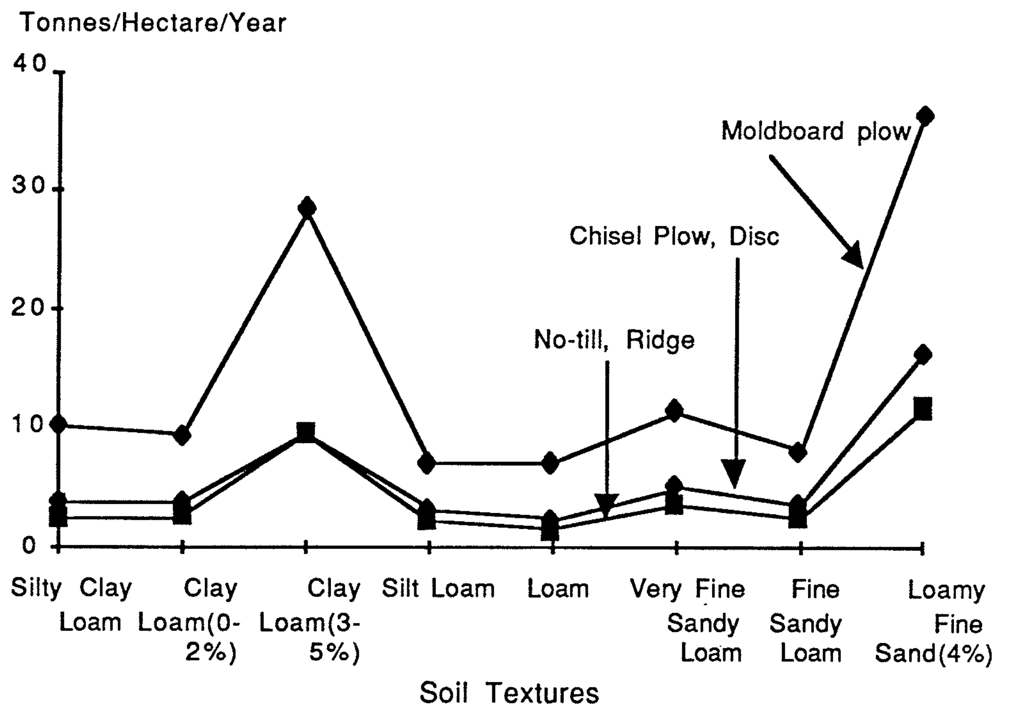

Figure 4.3: Average simulated soil loss under the five tillage systems with different soil texture and 2% slope (except two soils).

under different tillage systems. Moldboard plow again had the highest rate of average soil erosion in all slope classes. Chisel plow and disc were second highest except on 3% slope. The difference in average soil loss under chisel plow and no-till were very small up to 3% slope. Moldboard plow, however, was consistently much higher than all other conservation tillage practices throughout the 1 to 5% slope classes shown in Figure 4.4.

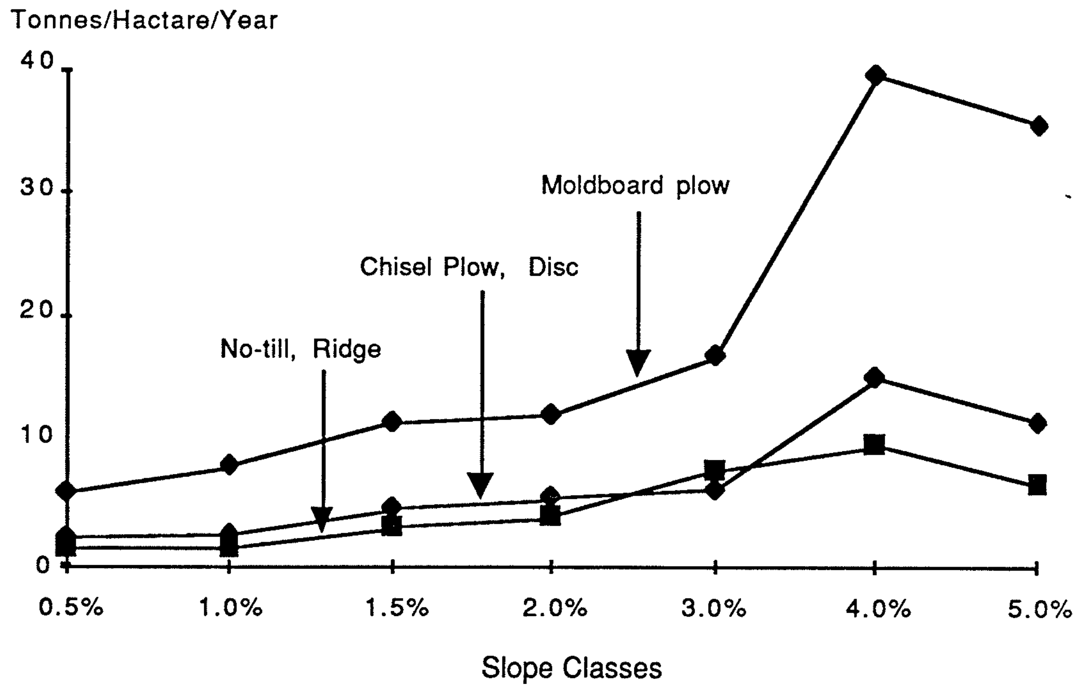

Figure 4.4: Average simulated soil loss under the five tillage systems in different slope classes.

Organic matter did not exhibit any influence on the rate of soil loss under different tillage practices. This is due to the fact that all soils in the study fields had over 4% organic matter content except two. It is believed that the amount of organic matter content over 4% will have little further influence on erodibility of the soil. Soil texture also affects the magnitude of the influence of organic matter content on erodibility (Langman 1982).

Slope length alone did not show any significant influence on soil loss under the various tillage systems in this study. Therefore, the only observable influence on soil loss from the data generated by COFARM is the degree of slope and tillage practices.

4.3 TILLAGE EFFECTS ON YIELD

All simulated yields appear to be too high as compared with the Manitoba projected value, 4.67 t/ha (75.7 bu/ac). Although the total average yields in the dry years simulated by COFARM were simular to that of Manitoba projected, the simulated yields in individual fields were quite high. The six fields having no yields lower the total average yields. Therefore, the total average simulated yields become seemingly close to that of Manitoba. Later section of this chapter (4.5.2.1) will discuss further about the validity of these results.

Corn yields were simulated in three moisture conditions, which were wet, average and dry years (Appendices C to E). The difference of yields under the five tillage systems varied from 0 to 0.5 t/ha (0 to 8 bu/ac). Most of the differences varied from 0 to 0.2 t/ha (0 to 3 bu/ac). The total average simulated yields under all tillage systems was highest in wet years and lowest in dry years (Table 4.3). Although the difference in yields does not seem to be high on a per hectare basis, the total yield difference times the current price per tonne would have some impact on a farmer's management decision.

In average years, ridge tillage was consistently among the highest yields in all soil types, except two fields. One was Glenboro VFSL and the other was Stockton FSL. Average corn yields on Firdale SiCL, Tiger Hill CL, Halstead SiCL and Doblin LFS exhibited no difference under the

TABLE 4.3

A summary of the total average simulated corn yields for the three simulated moisture conditions (t/ha).

	[1]MP	[2]CP	[3]NT	[4]Rdg	Disc
Wet years	8.0	8.1	8.1	8.2	8.1
Average years	7.4	7.5	7.5	7.5	7.4
Dry years	4.8	4.8	4.9	4.9	4.8

[1]Moldboard plow [2]Chisel plow
[3]No-till [4]Ridge tillage

five tillage systems. Under the moldboard plow tillage practice, average corn yields (7.4 t/ha) were among the lowest in most of the soils except two fields, one on Glenboro VFSL (8.6 t/ha) and another on Stockton FSL (8.3 t/ha). Corn yields under moldboard plow on these fields were both higher than those of under no-till. In most of the fields and soil types, overall corn yields were higher under conservation tillage.

In wet years, average corn yields for ridge tillage were consistently among the highest in all fields. There was no difference in average corn yields for all tillage systems on Croyon SiCL (9.2 t/ha), Dezwood CL (8.8 t/ha), Manitou CL (7.2 t/ha), Kaudson CL (6.8 t/ha) and Frostwick L (6.8 t/ha). In all soils, moldboard plow was among the lowest yield. The highest yield difference (+/- 0.3 t/ha or 5 bu/ac) under the five tillage systems was on Firdale SiCL.

In dry years, six fields had zero yield simulated for all tillage systems. Whether this was due to the processing error or the actual simulation result is unknown. Of three fields with Firdale SiCL, one field was among one of the zero t/ha yield for all tillage systems. The yields of all soil types under moldboard plow were consistently identical to that under disc tillage.

In wet, average and dry years, COFARM did not simulate any observable trend of yield difference for soil type under the five tillage systems. The only observation was that yield for moldboard plow was generally lower than that of the other conservation systems regardless of the soil type.

4.4 FEASIBILITY ASSESSMENT OF COFARM SYSTEM

Before a system is fully implemented, its applicability and effectiveness must be assessed. The resources and time required for the assessment was determined by the nature and complexity of the system. A common method to assess a system is comparison between an existing system and the new system being assessed. In the assessment of COFARM, there is no existing or similar computer system to compare with. One of the conventional approaches to assess this type of new system is the comparison of data collected from actual sites to that generated by COFARM. This would require the in situ data accumulated through a number of years in various locations throughout Manitoba. This approach, however, is not practical when only limited resources and time were available. Consequently, COFARM was assessed by satisfying the basic question: what are the sine qua non that a computer system should possess for the defined purpose?

4.4.1 System Analysis

One of the most important requirements for system analysis is to define clearly and concisely the objective or the purpose of the system to be developed at the outset. A system must be designed for the defined objective or purpose. A system could be well designed with high capability and performance. If it does not accomplish the original purpose, the system would be ineffective or even useless.

Soil conservation is the ultimate objective in acquiring a data base computer system. To accomplish this goal, the requirements for the data base computer system must be identified. The following basic questions address the requirements:

1. User environment - who would be the users?
2. Output requirement - what are the tasks required of the system?
3. Input requirement - what information are required by the system?

4.4.1.1 User Environment

Figure 2.1 identified the user environment. There are two basic categories of users - researchers and those who need recommendations. Researchers require COFARM to document the in situ farm data for the development of simulation models and further understanding of the relationships between soil characteristics and farming practices. Extension workers and farmers, on the other hand, expect COFARM to generate field recommendations.

4.4.1.2 Output Requirements

Since researchers may require information from COFARM that differs slightly from extension workers and farmers, the output of COFARM should meet this need.

Output contents and format

The primary interest of researchers is the influence of cropping systems on different variables. Information such as soil structure, moisture content, nitrogen level and other variables may be more meaningful and valuable to researchers. Farmers are interested in the tillage and fertilizer recommendation. Crop yield and soil erosion are required by all users but with varying degrees of importance. Soil conservationists may require the rate of soil erosion more than farmers who cannot quantify the soil loss in economic terms. COFARM satisfies these needs only in a limited sense. Users are able to document field data, generate recommendation and simulate soil loss and crop yield. Unfortunately, this output information is only available for one field at a time. Users cannot compare with another field without ending the session. Especially for scientific purposes in developing models and further understanding the interaction between soil characteristics and cropping patterns, a researcher would want to examine any changes or trends which occur under different fields or cropping systems. Therefore, COFARM should have been designed with the capability in tabulating or collating data of all fields into one document or file for examination.

During the comparative assessment of tillage practices on soil erosion and corn yield, data produced by COFARM cannot be readily used for comparison. All data from 18 fields simulated by COFARM must be recorded and tabulated manually in order to facilitate interpretation.

Output Media

Output media of COFARM is mainly screen output. There is restricted printer output in COFARM only through dumping screen output to a printer. Inessential information such as the menu list and commands are all printed. Paper and run time are, thus, needlessly wasted. Since COFARM does not have windowing screen output whereby more than one file can be examined at the same time on the screen, a well formatted printer output is even more essential. Farmers will be able to compare the performance of different fields, thereby management techniques can be evaluated. Researchers will be able to study the simulation model and discern new patterns or insights of cropping systems. The organized field data will also be filed by extension workers as inventory or census for the use of the department.

The output of COFARM is cumbersome and redundant. It takes the form of screen reports and screen prompts. Although the format of a report was well designed in COFARM, the user must view the entire report before proceeding to another operation. There is no exit at each screen page break. Nor is there reverse scrolling of screen page when the user wishes to view the previous page. These shortcomings of the COFARM system should not be ignored. The output requirements are directly related to the acceptance of the system by users. The system will likely be underused because needless time is required from the user. A user having over 10 fields to consider will find it senseless to look at the same long menu list each time the reports of another field are to be viewed.

COFARM also lacks graphic output. Although a user is able to compare the effects of different tillage practices, field to field comparison is impossible with COFARM. Graphic and tabulated report output of all fields combined would maximize the usefulness of the system.

4.4.1.3 Input Requirements

Data Collection

A questionnaire (Appendix G) was developed to collect data for COFARM, and input to the program is user friendly. Question prompts on the screen are identical to those of the questionnaire. The questionnaire, however, must be filled out before entering data to COFARM or before COFARM session begins. If there is no data input for a specific question, the user cannot proceed to the succeeding prompts or exit from the present session without ending it and losing all previous input. Similarly a user cannot go back to the previous prompt in most instances without ending the session. This rigid and time-consuming input procedure minimizes the desire to use the system.

Data Content

The questionnaire is useful to collect a wealth of information for developing a soil and crop data base. It can be divided into eight sections. The first 10 questions are used to collect personal data. The next section consists of 16 questions to compile the soil property data. Crop history, tillage practices, fertilizer uses, residue management and miscellaneous problems of the past three years are documented in the succeeding five sections. The final section is used to obtain data for the current seasonal recommendations or post-mortem analysis. A list of input variables can be found in Appendix F.

Since most farmers have limited knowledge of the soil type and texture, organic matter content, water holding capacity, depth to the water table and impermeable layer, bulk density, K factor, percent and length of slope, amount of erosion, assistance from an extension agent is required in filling out most of the these values in the soil property section.

There was a problem in entering data to question 16 which requests soil nitrogen level. The response must be "NO", otherwise the session would be discontinued with an error message. All previous data entered during the same session would be lost. To remedy this situation, a "NO" response was entered, even if the user had a recent soil nitrogen test, then the nitrogen level would have to be recorded to question 47.

In the crop history section, there are only 17 codes in question 27 (see Appendix G) representing different crops to be chosen for data input. There is no provision for crops other than the 17 options. There was one farmer growing canola in one year during 1983 to 1985. His crop history input for that year had to be falsely recorded. COFARM was unable to proceed unless all questions were satisfactorily answered. A user cannot skip any prompt, even if circumstances may deem it appropriate. The request for data of harvest population was not applicable in some instances. Harvest population is not generally recorded as such for alfalfa, wheat, potatoes and other crops. It was also found that no input could be made when the same field was divided for different crops in one of last three years. This rigid input procedure diminished the data input function. Its effectiveness and usefulness might, thus, be hindered.

There was also a similar problem in tillage and fertilizer history sections. The terminology of tillage and fertilizer application methods might differ slightly between the U.S. and Canada. Some farmers were not sure which code appropriately represented their tillage and fertilizer application methods.

Ambiguous definitions were found in the residue management section. Farmers had different opinions on the meaning of "all residue removed" and "no residue removed", which appeared in question 30. Some farmers felt that their corn residue plowed under was considered to be "no residue removed", since it remained on the field albeit under the soil. Others felt that "no residue removed" constituted that all standing stubble had to be left on top of the soil before they were plowed under or taken away. A more explicit term could be used to eliminate this ambiguity.

Questions in the miscellaneous section request only an arbitrary one-line description of the situation. The output, however, lists the problem in a specified way which may not coincide with the data entered

TABLE 4.4

An example of a srceen output of field data.

```
***** FIELD TREATMENTS AND PROBLEMS

      HERBICIDES USED?       : YES
      TYPE, AMOUNT, DATE   : MILLET

      WEED PROBLEM?          : YES
      TYPE, SEVERITY         : MILLET
```

(Table 4.4). The prompt for this question should have been more specific and concise so that a user will provide suitable information to match output format. When output formatted as "TYPE AND AMOUNT", for instance, the input prompt should indicate likewise, rather than a vague prompt statement "ENTER A ONE-LINE DESCRIPTION OF THE SITUATION".

COFARM documents only three years of crop, tillage, fertilizer, residue history and the miscellaneous problems. A user cannot input information for less or more than three years. This may, therefore, limit the potential for researchers.

Editing Input Data

To ensure accurate data input, errors should be detected as data are being keyed in. Since data input involves human error, input should be checked for its reasonableness, range, validity, class and completeness.

1. **Reasonableness check.** It would be reasonable to have only positive values including zero for all the input variables in COFARM. COFARM detects and rejects all negative input values.

2. **Range check.** Data tested against upper and/or lower limits is a form of range check. All the COFARM input questions have range check. A typical example is the sum of the numbers for N-P-K of a fertilizer product could not exceed 100 since these numbers in COFARM reflect the percentage of the N-P-K mixture of fertilizer. When user input these number with the sum exceeding 100, COFARM gave a message indicating range had been exceeded. A user, therefore, must divide all three numbers proportionally to lower the sum until it is less than or equal to 100.
3. **Validity Check.** By comparing with the previously established data that was already in the system, the validity of the input data was checked. When counties other than those in the county list of COFARM were entered, the COFARM session could not proceed furthér. In order for the data collected to be analyzed by COFARM, Manitoba farm locations in this study were randomly assigned to one of the counties on the list.
4. **Class Check.** Data must be checked for whether numeric or alphabetic input. COFARM prompts would not accept input when data were not in the proper class requested.
5. **Completeness Check.** All COFARM prompts must be answered in order to proceed. This ensured no blanks occurred in the data field. The disadvantage of this check is the rigidity as described previously. COFARM should have provision for "N/A" or "0" where appropriate so that data would be completed without entering false data into the system. For example, if a field was fallowed or was not under cultivation in one of the previous three years, question 28 of the questionnaire should have provided "N/A" or

"other" in the list of choices to be entered. Therefore, when a completeness check is properly designed, the problem of rigidity will be eliminated or minimized.

4.5 COFARM APPLICABILITY

The foregoing analysis primarily focused on the design of the COFARM to elucidate part of the effectiveness of the system.

4.5.1 Effectiveness

Effectiveness in this analysis implies several measures of report usefulness. If the result generated by a system could or would not be used, the system would be ineffective. Timeliness in providing valuable information is one of the important components for decision making. An effective system will deliver timely output to be used. In order to generate recommendations and yield prediction, climatic data is required. Precipitation values for each month (April through August) can either be entered directly by a user, or a user selects a qualitative choice of wet, average, or dry year, or COFARM provides the best estimate as read from an existing file. Seasonal temperatures can also be entered in similar ways. To have timely recommendations just before the growing season begins, files containing climatic data must be updated. This might not be feasible since there is no system linkage between COFARM and systems in Environment Canada. The only alternative is to obtain their predicted climatic values and input to COFARM manually. Since COFARM is on a microcomputer, a network would be advantageous to update climatic data if many systems throughout Manitoba are installed.

Accuracy of output is another aspect for effectiveness. Certainly, to question the accuracy (not validity) of the simulation model in COFARM is beyond the scope of this study. Authors of COFARM indicated that the predicted values are within 15-20 percent of the observations. It should be noted that COFARM simulation model was developed in the U.S. The level of accuracy might vary when COFARM is used in a Manitoba situation. The COFARM model was developed for use in the corn belt area, and Shaffer and Johnson (1985) suggested that some modification of the field and soil variables would probably be required if used elsewhere.

4.5.2 Applicability

The applicability of a system is largely dependent on its output validity and reliability, although they are related. A system could be very effective in accomplishing its defined tasks. If it is not applicable to users for the given situation, the system should not be implemented.

4.5.2.1 Validity

Validity of the results generated by a system means they are appropriate or unbiased. The validity of the COFARM simulation model cannot be fully assessed in this study unless in situ data were available for comparison. Corn yield and soil erosion values produced by COFARM simulation models might not be valid and reliable for the Manitoba condition. Part of the reason was the climatic data used for the simulation. There are three options for users to enter precipitation data. Users may estimate or provide actual seasonal precipitation values, either monthly or daily. Another option is the computer estimation of rainfall values. During this study, local actual precipitation values were entered. COFARM failed to accept these values. Consequently, all the precipitation values were estimated by COFARM. Computer estimated precipitation values during the months of May through September were different in total and individual months than observed values. The yield and, perhaps, the soil loss predicted by COFARM might not reflect the true values for the study area.

Four counties were used to check whether differences of precipitation values would be significant. Dakota, Scott, Rice and Le Seur all had the same computer estimated rainfall values. The total rainfall estimated by COFARM during the five-month period was higher than that collected from five weather stations within the study area (Table 4.5). The lowest was 275.1 mm and the higher was 423.7 mm. The computer estimated value was 472.4 mm. This would have a considerable influence on corn yield and erosion. The distribution of rainfall during the five-month period from the computer estimation was also different from the actual collected values. According to the collected data, the peak precipitation was in the month of July. However, COFARM estimated the peak rainfall was in May. This is critical, especially, for the prediction of the soil erosion rate. In the month of May, vegetative cover is generally minimal unless zero-till is practiced. Higher rainfall in the month of May could cause higher soil loss than that of the later growing season. The rate of soil erosion will diminish when the field is covered by a germinated crop. Therefore, the high rainfall in July in Manitoba would not contribute as much soil loss as in May in the U. S. In terms of

TABLE 4.5

Monthly total rainfall (mm) from May to September 1986 collected in the study area.

Stations	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL
Rathwell[1]	59.4	106.4	147.3	31.2	79.3	423.7
Holland[1]	59.9	71.1	123.4	44.5	53.3	352.3
Deerwood[1]	63.5	77.5	115.1	17.8	53.3	327.2
Miami Orchard[1]	61.0	66.3	118.1	18.8	36.8	301.0
Manitou Strange[1]	30.5	57.7	112.0	30.7	44.2	275.1
Dakota (from COFARM)	132.1	81.3	83.8	78.7	96.5	472.4

[1]Source: Environment Canada.

yields, if zero-till is used, excessive moisture may impede germination in some instances, especially on poorly drained soils (Crosson 1981).

The yield prediction simulated by COFARM was developed only for grain corn, however, input data were for silage corn. On the basis of this criterion alone, yield data generated by COFARM would not be valid for the participants. Assuming the input data were for grain corn, the mean yield estimated by Manitoba Agriculture was 4.67 t/ha (75.5 bu/ac) at 15.5% moisture (MDA 1985). Yields for grain corn estimated by COFARM were much higher for all tillage system on all soil types. This could probably be due to the higher heat unit and precipitation and different hybrids used in Minnesota. Yield projections for grain corn from COFARM, thus, definitely are not be valid for grain corn growers in Manitoba.

Since the model was developed in the U.S. cornbelt, users may question its validity in other areas. This also relates to the attitude toward the reliability of recommendations generated by COFARM. If farmers do not feel the data reliable enough to follow, the acceptance or use of COFARM will be minimal. COFARM might be modified or a similar system might be developed.

4.5.3 Modification of the System

4.5.3.1 Strength of Coupling

To determine the level of complexity in modifying a system, the coupling and cohesion of modules within the system need to be examined. The weaker the coupling, the less difficult the modification. There are only two modules in COFARM. Their strength of coupling is strong. The simulation module needs to access data from data base management module to generate predictions. A change of one variables in one module will unavoidably affect the other. The strength of coupling is influenced by the complexity of interface between the two modules. For example, the list of counties consists only of those for which the model is developed. If COFARM is going to be implemented in Manitoba, the county list must be changed to Manitoba municipality names. The subroutine that identifies the county agents must, therefore, be replaced. Furthermore, soil data base would not match the county name. Consequently, simulation would not be performed. This illustrates that the strength of coupling in COFARM determines the complexity of modification. When there are so many changes needed, the time and resources required would probably be as much as, if not greater than, development of a new system for Manitoba. The modified COFARM program may not satisfy the needs for users and, thus, fulfill the ultimate goal in contribution to soil conservation.

4.5.3.2 Strength of Cohesion

The cohesion of modules also determines the level of complexity in modifying a system. When a module has a single well-defined function, it is said to have maximum cohesion. For a module to be cohesive, it should perform only one function. In COFARM, the data management module consists of about 50 subroutines which comprises about 7700 lines. Although its primary function is for data entry, each subroutine performs a function. The data management module, thus, operates a number of functions. Similarly, the simulation module has about 28 subroutines written in about 3700 lines. Many functions are also performed in the simulation module.

A system with strong cohesion and weak coupling is less difficult to modify. As the foregoing examination of COFARM has shown, it appears to be extremely time consuming to modify the over 10,000 lines of a non-cohesive and strong coupling system. The amount of time and resources required may warrant a new system be developed. This, however, does not imply COFARM is completely useless. COFARM can be used as a prototype in developing a new system for Manitoba condition. Perhaps, a new system would be developed with the improvement of weaknesses that exist in COFARM. More users would be absorbed and researchers would find the new system useful for their research activities. Farmers would have confidence in following the recommendations and prediction for their farming practices. This would have a positive impact toward the goal of soil conservation. As the knowledge and understanding of the interaction between soil property and farming activities increase, better simulation models and management techniques can be developed. More farmers would be knowledgeable about the impact of their farming techniques and inclined to the recommendations generated from the system. This will enhance the use and management of the soil resource.

Chapter V

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The COFARM computer program was designed to assist in collecting farm data and to generate management recommendations. Researchers may collect data for developing simulation models, and for further understanding the interaction of soil characteristics and farming practices. Farmers and extension workers may obtain management recommendations. The ultimate goal of designing this or a similar system is to assist farmers in making management decisions and increase the awareness of effects resulted from different tillage practices. In order to reach this goal, the acceptance, effectiveness and applicability of this kind of system is important. The strengths and weaknesses of the COFARM system are shown in Table 5.1.

TABLE 5.1

Strengths and weaknesses of COFARM determined from this study.

STRENGTH	WEAKNESS
User friendly	Redundant screen output
Comprehensive questionnaire for data collection	Rigid input procedure
Good data content	Lack of comprehensive tabulated output of all fields
Complete editing input mechanism	Only three years input data allowed
Powerful simulation model	Strong coupling and weak cohesion
	Disputable validity and reliability of simulated output for Manitoba condition

5.1.1 Data Compilation

1. COFARM may be used to compile three consecutive years of tillage, crop, fertilizer, residue history, miscellaneous problems and soil property for individual farms.
2. COFARM cannot form a data base of these farm data for more than a 3-year span.
3. COFARM cannot tabulate all the field data together into one file or document.

5.1.2 Tillage Effects

4. By means of COFARM, the effects on soil erosion and corn yields under conservation and moldboard plow were compared. The rate of soil erosion in all soil types as well as all textural and slope classes under moldboard plow was the highest among all tillage systems.
5. Among conservation systems, no-till and ridge-till had the same effect on soil loss in all fields. Chisel plow and Disc had an identical effect on soil erosion and greater than No-till and Ridge-till.
6. Soil loss for all tillage systems increased as the degree of slope increased.
7. Tillage effect on yield was small on a per acre basis.
8. Corn yield was generally lower for the moldboard plow on most of the soil types and moisture conditions.

5.1.3 COFARM Applicability in Manitoba

9. The COFARM computer system may be useful only as a prototype.
10. Simulation output is not applicable to silage corn growers in Manitoba.

5.2 RECOMMENDATIONS

I recommend the development of a new computer system called MANFARM similar to COFARM for Manitoba conditions. The detailed design of an interactive data base computer system is beyond the scope of this study. The following recommendations should provide a general guideline for MANFARM to be designed.

5.2.1 System Objective

1. Data base management of farm data that can interact with simulation models.

5.2.2 Output Requirements

2. Tabulated individual as well as combined field data.
3. Screen and printer output capability.
4. Graphic capability is desirable.

5.2.3 Input Requirements

5. A questionnaire similar or identical to that of COFARM (Appendix G).
6. Unlimited year span of data input.
7. Editing input data should include sequence, reasonableness, range, validity, comparison, class, completeness checks.

8. Input prompts should be concise rather than the long questions identical to the questionnaire, though the question number should be the same.
9. The system should be divided into more modules so as to maximize cohesion and minimize coupling. Figure 5.1 illustrates MANFARM's general structure.
10. Climatic data, advisory comments from extension officials and data from Soil Survey should be collected by an individual program which would write to a file that can be read by the system for simulation. The updated information can then be transfered to all users by a floppy disk when a modem or network is not available.
11. A network system would be advantageous but might not be feasible economically. The new system can be installed in all extension offices throughout Manitoba. Farmers may submit their completed questionnaires to the extension offices. They also may acquire the program and send their printed output to extension offices. Another alternative is to have questionnaires sent to farmers and returned to the Winnipeg office for analysis. The compliance, however, may not be optimal.

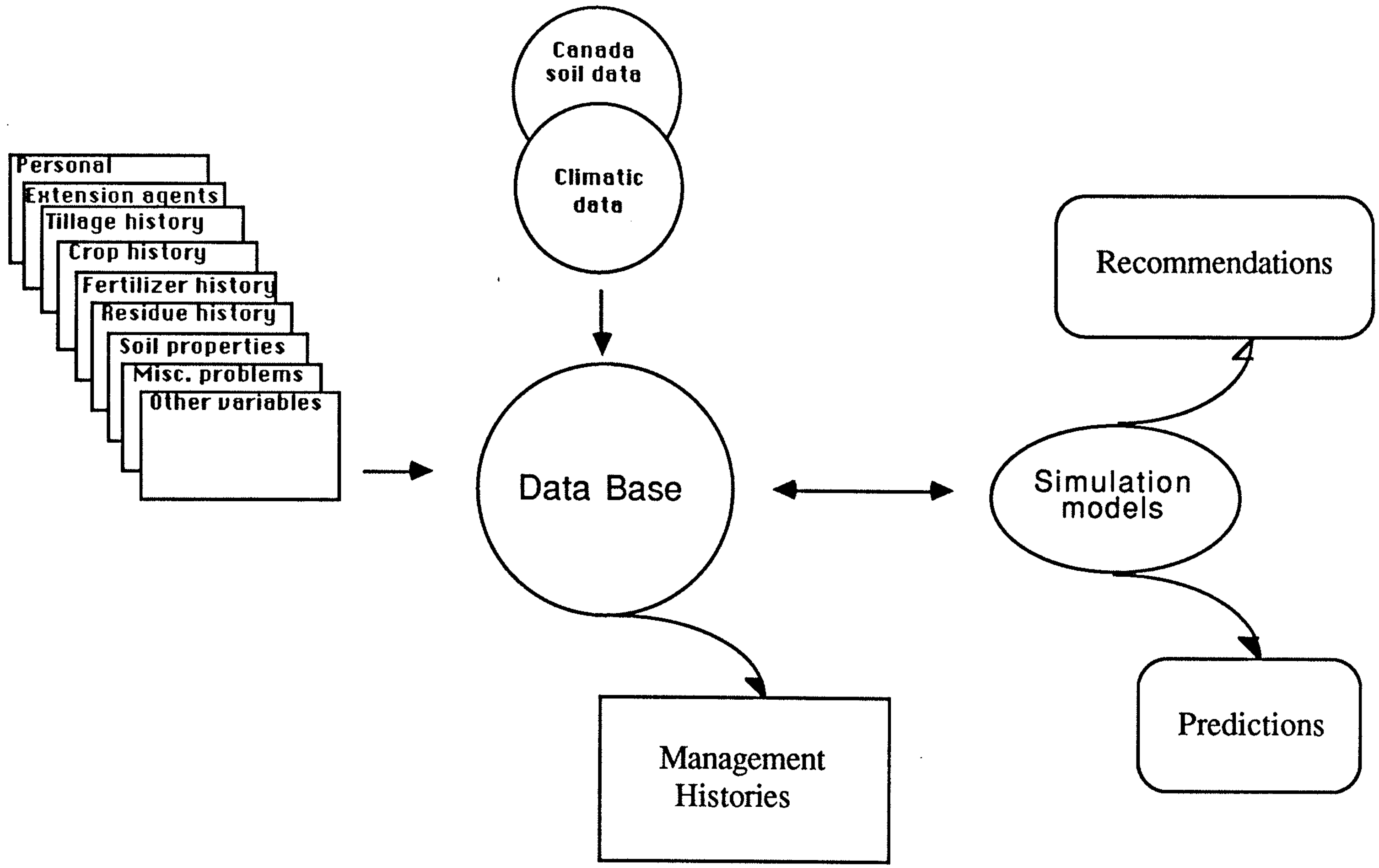

Figure 5.1: A schematic diagram illustrates the structure of the proposed system (MANFARM)

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Appendix A

DEFINITIONS OF TERMS

Class check An edit test determines whether data in a field is numeric or alphabetic.

Cohesion The characteristic of a module with a single, well-defined funtion.

Comparison check An edit test that compares related items.

Completeness check An edit test that determines whether required data items are present.

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

Conventional tillage The combination of primary and secondary tillage operations normally performed in preparing a seedbed for a given crop grown in a given geographical area. It is generally referred to moldboard plow tillage practices.

Coupling The relationship between modules, which ideally should be weak.

Module A set of logically related program statements that perform a specific function.

Program A series of instructions that direct the computer system to perform a specific operation.

Prompt A screen design approach that asks users simple questions or promts with symbol.

Prototypes Models that are developed, experimented with, modified, and discarded when a better model can be made.

Range check An edit test that compares data to upper and/or lower limits.

Reasonableness check An edit test that evaluates data against some reasonable standard.

Scrolling Moving text up and down, right or left on a screen. Horizontal scrolling lets the screen show lines of text that are wider than the screen itself. Vertical scrolling is the most common form used and provides the capability to change the display by moving text up or down.

Soil erosion The detachment and movement of soil from the land surface by wind or water.

Summer fallow The tillage of uncropped land during the summer to control weeds and store moisture in the soil for the growth of a later crop.

Submodels Computer models that directly access a data base system to generate management recommendations and predictions.

System analysis Involves defining the problem to be solved or the opportunity to be seized, and determining what the objectives of a new, improved system will be.

Validity check An edit test used to establish the validity of data.

Windowing The ability to display several different outputs in different locations on the screen at the same time.

Zero-tillage (no-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; usually involves opening a small slit or punching a hole into the soil; usually no cultivation during crop production; chemical weed control is normally used; also called slot planting.

Appendix B

SUMMARY OF SIMULATED EROISON RATES ON DIFFERENT SOIL TYPES UNDER FIVE TILLAGE SYSTEMS.

Soil Types	Moldboard plow		Chisel plow		No-till		Ridge tillage		Disc	
	t/ha	t/ac	t/ha	t/ac	t/ha	t/ac	t/ha	t/ac	t/ha	t/ac
CROYON SiCL	13.9	6.2	4.5	2.0	2.7	1.2	2.7	1.2	4.5	2.0
FIRDALE SiCL	12.5	5.6	5.6	2.5	4.0	1.8	4.0	1.8	5.6	2.5
FIRDALE SiCL	12.1	5.4	3.8	1.7	2.2	1.0	2.2	1.0	3.8	1.7
FIRDALE SiCL	6.5	2.9	2.9	1.3	2.0	0.9	2.0	0.9	2.9	1.3
DANLIN SiCL	5.8	2.6	2	0.9	1.1	0.5	1.1	0.5	2.0	0.9
DEZWOOD CL	43.2	19.3	14.1	6.3	8.3	3.7	8.3	3.7	14.1	6.3
DEZWOOD CL	35.8	16.0	11.7	5.2	6.7	3.0	6.7	3.0	11.7	5.2
DARLINGFORD CL	18.1	8.1	5.8	2.6	3.4	1.5	3.4	1.5	5.8	2.6
DARLINGFORD CL	15.9	7.1	6.7	3.0	4.5	2.0	4.5	2.0	6.7	3.0
TIGERHILL CL	12.3	5.5	5.6	2.5	4.0	1.8	4.0	1.8	5.6	2.5
RAMADA CL	11.7	5.2	5.4	2.4	3.8	1.7	3.8	1.7	5.4	2.4
MANITOU CL	10.1	4.5	3.4	1.5	2.0	0.9	2.0	0.9	3.4	1.5
MANITOU CL	7.8	3.5	2.5	1.1	1.6	0.7	1.6	0.7	2.5	1.1
MANITOU CL	6.9	3.1	3.1	1.4	2.2	1.0	2.2	1.0	3.1	1.4
KAUDSON CL	7.6	3.4	2.5	1.1	1.6	0.7	1.6	0.7	2.5	1.1
HALSTEAD SiCL	10.1	4.5	4.5	2.0	3.1	1.4	3.1	1.4	4.5	2.0
FAIRLAND SiCL	4.0	1.8	1.8	0.8	1.1	0.5	1.1	0.5	1.8	0.8
FROSTWICK L	6.9	3.1	2.2	1.0	1.3	0.6	1.3	0.6	2.2	1.0
GLENBORO VFSL	11.4	5.1	5.2	2.3	3.6	1.6	3.6	1.6	5.2	2.3
STOCKTON FSL	10.1	4.5	4.5	2.0	3.1	1.4	3.1	1.4	4.5	2.0
STOCKTON FSL	5.8	2.6	2.5	1.1	1.6	0.7	1.6	0.7	2.5	1.1
DOBLIN LFS	36.3	16.2	16.4	7.3	1.7	5.2	1.7	5.2	16.4	7.3
Total average	13.9	6.2	5.4	2.4	3.4	1.5	3.4	1.5	5.4	2.4

Appendix C

SUMMARY OF SIMULATED CORN YIELDS (GRAIN) UNDER FIVE TILLAGE PRACTICES IN WET YEARS.

Soil Types	Moldboard plow		Chisel plow		No-till		Ridge tillage		Disc	
	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr
CROYON SiCL	9.2	146	9.2	146	9.2	146	9.2	146	9.2	146
FIRDALE SiCL	8.8	140	9.3	148	9.0	143	9.3	148	9.0	143
FIRDALE SiCL	8.4	134	8.9	141	8.6	136	8.9	141	8.6	137
FIRDALE SiCL	8.1	129	8.1	129	8.1	129	8.1	129	8.1	129
Average	8.4	134	8.7	139	8.6	136	8.7	139	8.6	136
DANLIN SiCL	8.6	136	8.6	136	8.6	136	8.6	137	8.6	136
DEZWOOD CL	8.4	134	8.4	134	8.4	134	8.4	134	8.4	134
DEZWOOD CL	9.2	146	9.2	146	9.2	146	9.2	146	9.2	146
Average	8.8	140	8.8	140	8.8	140	8.8	140	8.8	140
DARLINGFORD CL	6.8	108	6.8	108	6.8	108	6.8	108	6.8	108
DARLINGFORD CL	8.3	132	8.4	133	8.4	134	8.4	134	8.3	132
Average	7.6	120	7.6	121	7.6	121	7.6	121	7.6	120
TIGERHILL CL	8.5	135	8.5	135	8.6	136	8.6	136	8.5	135
RAMADA CL	7.2	114	7.3	116	7.3	116	7.4	117	7.2	115
MANITOU CL	7.7	123	7.7	123	7.8	124	7.8	124	7.7	123
MANITOU CL	7.3	116	7.3	116	7.3	116	7.3	116	7.3	116
MANITOU CL	6.6	105	6.6	105	6.7	106	6.7	106	6.6	105
Average	7.2	115	7.2	115	7.2	115	7.2	115	7.2	115
KAUDSON CL	6.8	108	6.8	108	6.8	108	6.8	108	6.8	108
HALSTEAD SiCL	9.3	147	9.4	150	9.4	150	9.4	150	9.4	149
FAIRLAND SiCL	9.2	146	9.2	146	9.3	147	9.3	147	9.2	146
FROSTWICK L	6.8	108	6.8	108	6.8	108	6.8	108	6.8	108
GLENBORO VFSL	7.6	121	7.8	124	7.7	122	7.9	125	7.7	123
STOCKTON FSL	7.2	114	7.3	116	7.3	116	7.4	117	7.2	115
STOCKTON FSL	7.1	113	7.1	113	7.2	114	7.2	114	7.1	113
Average	7.2	114	7.2	115	7.2	115	7.3	116	7.2	114
DOBLIN LFS	9.6	153	9.9	157	9.9	157	9.9	157	9.8	156
Total average	8.0	128	8.1	129	8.1	129	8.2	129	8.1	128

Appendix D

SUMMARY OF SIMULATED CORN YIELDS (GRAIN) UNDER FIVE TILLAGE PRACTICES IN AVERAGE YEARS.

Soil Types	Moldboard plow		Chisel plow		No-till		Ridge tillage		Disc	
	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr
CROYON SiCL	7.5	119	7.6	120	7.7	122	7.7	122	7.5	119
FIRDALE SiCL	9.2	145	9.2	145	9.2	145	9.2	145	9.2	145
FIRDALE SiCL	8.7	139	8.7	139	8.7	138	8.7	139	8.7	139
FIRDALE SiCL	7.0	111	7.0	112	7.1	113	7.1	113	7.0	111
Average	8.3	132	8.3	132	8.3	132	8.3	132	8.3	132
DANLIN SiCL	7.2	114	7.2	114	7.3	116	7.3	116	7.2	114
DEZWOOD CL	7.7	123	7.7	123	7.7	123	7.7	123	7.7	123
DEZWOOD CL	7.6	121	7.7	122	7.8	124	7.8	124	7.6	121
Average	7.7	122	7.7	123	7.8	124	7.8	124	7.7	122
DARLINGFORD CL	5.4	86	5.4	86	5.5	88	5.5	88	5.4	86
DARLINGFORD CL	7.6	120	7.7	122	7.9	126	7.9	126	7.6	120
Average	6.5	103	6.5	104	6.7	107	6.7	107	6.5	103
TIGERHILL CL	7.7	122	7.7	122	7.7	122	7.7	122	7.7	122
RAMADA CL	9.6	153	9.7	154	9.8	155	9.8	155	9.6	153
MANITOU CL	6.4	101	6.4	102	6.5	104	6.5	104	6.4	101
MANITOU CL	6.7	106	6.7	106	6.7	106	6.7	106	6.7	106
MANITOU CL	5.4	85	5.4	85	5.4	86	5.4	86	5.4	85
Average	6.1	97	6.2	98	6.2	99	6.2	99	6.1	97
KAUDSON CL	5.4	85	5.4	86	5.5	87	5.5	87	5.4	85
HALSTEAD SiCL	8.6	136	8.6	136	8.6	136	8.6	136	8.6	136
FAIRLAND SiCL	8.9	141	9	143	9.3	147	9.3	147	8.9	141
FROSTWICK L	5.4	85	5.4	86	5.5	87	5.5	87	5.4	85
GLENBORO VFSL	8.6	136	8.8	140	8.4	133	8.6	137	8.8	140
STOCKTON FSL	8.3	132	8.4	134	8.2	130	8.3	132	8.4	134
STOCKTON FSL	5.8	92	5.8	92	5.9	93	5.9	94	5.8	92
Average	7.0	112	7.1	113	7.0	112	7.1	113	7.1	113
DOBLIN LFS	8.8	140	8.8	140	8.8	140	8.8	140	8.8	140
Total average	7.4	118	7.5	119	7.5	119	7.5	120	7.4	118

Appendix E

SUMMARY OF SIMULATED CORN YIELDS (GRAIN) UNDER FIVE TILLAGE PRACTICES IN DRY YEARS.

Soil Types	Moldboard plow		Chisel plow		No-till		Ridge tillage		Disc	
	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr	t/ha/yr	bu/ac/yr
CROYON SiCL	6.7	107	6.8	108	6.9	110	6.9	110	6.7	107
FIRDALE SiCL	0	0	0	0	0	0	0	0	0	0
FIRDALE SiCL	7.9	125	8.0	127	7.9	125	8.1	129	7.9	125
FIRDALE SiCL	7.0	111	7.0	112	7.2	114	7.2	114	7.0	111
Average*	5.0	79	5.0	80	5.0	80	5.1	81	5.0	79
DANLIN SiCL	7.0	112	7.1	113	7.2	114	7.2	115	7.0	112
DEZWOOD CL	8.2	131	8.2	131	8.3	132	8.3	132	8.2	131
DEZWOOD CL	7.0	111	7.0	112	7.1	113	7.2	114	7.0	111
Average	7.6	121	7.7	122	7.7	123	7.7	123	7.6	121
DARLINGFORD CL	6.0	96	6.0	96	6.0	96	6.2	98	6.0	96
DARLINGFORD CL	5.7	91	5.8	92	6.0	96	6.0	96	5.7	91
Average	5.9	94	5.9	94	6.0	96	6.1	97	5.9	94
TIGERHILL CL	6.4	102	6.5	103	6.4	102	6.6	105	6.4	102
RAMADA CL	7.2	114	7.2	115	7.4	118	7.6	120	7.2	114
MANITOU CL	5.6	89	5.7	90	5.8	92	5.8	92	5.6	89
MANITOU CL	7.6	120	7.6	120	7.6	121	7.6	121	7.6	120
MANITOU CL	5.4	86	5.5	87	5.5	88	5.5	88	5.4	86
Average	6.2	98	6.2	99	6.3	100	6.3	100	6.2	98
KAUDSON CL	0	0	0	0	0	0	0	0	0	0
HALSTEAD SiCL	0	0	0	0	0	0	0	0	0	0
FAIRLAND SiCL	0	0	0	0	0	0	0	0	0	0
FROSTWICK L	0	0	0	0	0	0	0	0	0	0
GLENBORO VFSL	5.8	92	5.9	94	6.0	96	6.2	98	5.8	92
STOCKTON FSL	5.6	89	5.7	91	5.9	93	6.0	95	5.6	89
STOCKTON FSL	5.6	89	5.7	90	5.7	90	5.8	92	5.6	89
Average	5.6	89	5.7	91	5.8	92	6.0	93	5.6	89
DOBLIN LFS	0	0	0	0	0	0	0	0	0	0
Total average	4.8	76	4.8	76	4.9	77	4.9	78	4.8	76

Appendix F

SUMMARY OF INPUT VARIABLE FOR COFARM

Question numbers	Description of input variables
	Soil property section
12	Number of soils in the field
13a	Soil type code
13a	Percent of each soil type in field
13a	Number of soil textures in field
13b	Soil textural class code
13b	Percent of each textural class
14	Presence or absence of tile drain
14	Depth of tile lines (if present)
14	Horizontal spacing of tiles (if present)
15	Presence or absence of plow pan
15	Depth of plow pan (if presence)
16	Availability of recent soil test data
16	Soil test nitrogen level (if available)
16	Date of soil N test (if available)
16	Depth of soil N test (if available)
17	Percent soil organic matter
18	Soil water holding capacity
19	Depth to permanent water table
20	Depth to impermeable barrier
21	Soil bulk density
22	K factor
23	Predominant percent slope
24	Predominant length of slope
25	Severity of erosion
26	Predominant orientation of slope
	Crop history section
27	Crop grown in each of last three years
27	crop yield
27	Plant population
27	Planting date
	Tillage history section
28	Number of tillage operations in each of last three years
28	Tillage mothod code
28	Tillage depth

Appendix F

	Fertilizer history section
29	Number of fertilizer or manure applications in each of the last three years
29	Fertilizer application method
29	Fertilizer type
29	Rate of Fertilizer application
29	Percent N in fertilizer
29	Percent P in fertilizer
29	Percent K in fertilizer
	Residue history section
30	Residue management practice for each of past three years
30	Percent of residue removed
	Miscellaneous problems section
31	Herbicide use
32	Weed problem
33	Pesticide use
34	Disease problem
35	Drainage problem
36	Irrigation practices

Appendix G

COFARM QUESTIONNAIRES

1. Name -- first   middle initial   last

---

2. Street address -- number and street or rural identification

---

3. City, state, and postal code

---

4. phone number -- area code

---

5. County

---

6. Section, township, and range for your farm or fields

---

7. Enter location of nearest weather station

---

8. If you have a rain guage, soil moisture measuring device, or soil auger, enter the type of device here

---

9. Enter a new password to identify and protect your records. Enter four characters -- use letters and/or numbers

---

10. Enter your I.D. for your field. Enter a maximum of 7 characters -- use letters and/or numbers

---

Refer to the attached county soil tables for questions 11 - 13

11. If you know which soil type(s) are in your field enter "yes". If you do not know your soil types, enter "no" and contact your local county extension agent for assistance, and skip to question 27.

---

12. Enter the number of different soil types in your field

____

13a. Using the attached table, enter your soil types and percents: for example, if you have half (50 percent) Atamont loam and half Pembina clay loam, you would enter: 21 50, 18 50

____

13b. For each of your soils enter the texture

Example:	Soil Name	Texture
	Pembina	Clay loam

Soil Name	Texture	Soil Name	Texture

Anwser questions 14 - 25 for each soil in this field

14. Is your field tile drained (or tube drained)? Enter "yes" or "no". (If "no" for the whole field, skip to question 15.)

X____

Soil	Tile Depth	Tile spacing

15. Does your field have a plow pan or other condition which interferes with drainage or root growth? enter "yes" or "no". (If "no" for the whole field, skip to question 16.)

X____

Soil	Pan depth (inches)

16. Have you had a recent soil test for nitrogen? --enter "yes" or "no" (If "no", skip to question 17.)

X____

Enter soil test nitrogen level in lbs-N per acre, date of sampling and depth of sampling (0-2 ft. or 0-4 ft.)

Soil	lbs. N/A	Date	Depth
Ex: Altomont	44	4/13/85	0-4

17. *# Enter the percent organic matter in your soil (top foot):
(If percent not known, enter high, medium, or low)

Soil	Organic matter %	Soil	Organic matter %
____________	__________	___________	____________
____________	__________	___________	____________
____________	__________	___________	____________
____________	__________	___________	____________

18. *# Enter the water holding capacity of your soil to 5 foot depth or limit of rooting (use inches water per five ft. depth, or use one of the codes below.)

1 High
2 Medium
3 Low
4 Don't know

Soil	Water holding capacity	Soil	Water holding capacity
_________	_____________	___________	______________
_________	_____________	___________	______________
_________	_____________	___________	______________
_________	_____________	___________	______________

19. *# Enter the depth to the water table, in feet

Soil	Water table	Soil	Water table
_________	_____________	___________	______________
_________	_____________	___________	______________
_________	_____________	___________	______________
_________	_____________	___________	______________

*If you leave this question blank, the computer will provide a value.
\# A county extension agent should assist in answering this question.

20. *# Enter the depth to the bedrock or impermeable barrier (in ft.)

Soil	Bedrock depth	Soil	Bedrock depth

21. *# Enter the bulk density of each soils for the ranges of 0-2 Ft. and 2-5 Ft.

Soil	0-2 Ft.	2-5 Ft.

22. *# Enter the Erosion K Factor of each of your soils

Soil	Erosion Factor

*If you leave this question blank, the computer will provide a value.
A county extension agent should assist in answering this question.

23. *# Enter the percent slope of your field -- for example, 0, 1.5, 2.5, or 7, etc. If there is no slope to your fields, enter 0

Soil	% slope	Soil	% slope
____________	__________	_____________	__________
____________	__________	_____________	__________
____________	__________	_____________	__________
____________	__________	_____________	__________

24. #Enter the average length of your slope in feet

Soil	length	Soil	length
___________	___________	_____________	__________
___________	___________	_____________	__________
___________	___________	_____________	__________
___________	___________	_____________	__________

25. #Enter the amount of erosion of the slope using one of the codes below:

1 None to slight
2 Moderate
3 severe

Soil	Erosion code
________________________	___________________________
________________________	___________________________
________________________	___________________________
________________________	___________________________
________________________	___________________________
________________________	___________________________
________________________	___________________________
________________________	___________________________

*If you leave this question blank, the computer will provide a value.
A county extension agent should assist in answering this question.

26. # Enter the predominant direction of the slope -- enter "N", "NE", "E", "SE", "S", "SW", "W", "NW" for a slope that goes down to the north, down to the northeast, down to the east, down to the southeast, etc.

Soil	Direction	Soil	Direction

A county extension agent should assist in answering this question.

27. For this field, enter your crops and yields for the past 3 years. Use the crop codes from the table below. Enter yields in units of bushels or tons or pounds per acre -- whichever is shown in the table for your crop.

Code	Crop	Units
1	Alfalfa	Tons/A
2	Corn (for grain)	Bu/A
3	Corn (for silage)	Ton/A
4	Oats	Bu/A
5	Wheat	Bu/A
6	Barley	Bu/A
7	Rye	Bu/A
8	Flax	Bu/A
9	Soybeans	Bu/A
10	Beans (Navy, Pinto, and other dry edible beans)	Lbs/A
11	Sugarbeets	Tons/A
12	Sunflowers	Lbs/A
13	Red clover, birdsfoot trefoil alsike, legume-grass	Tons/A
14	Potatoes	Lbs/A
15	Meadow or fallow	---
16	Sweetcorn	Tons/A
17	Peas	Lbs/A

For example, if you grew alfalfa last year, and corn for grain the previous two years, then you would enter:

	Crop:	Yield:	Planting Date:	Harvest population (plants/acre):
Last year:	1	4.3	6/13/81	400
Two years ago:	2	156	5/03/80	23000
Three years ago:	2	144	5/13/79	20000

	Crop:	Yield:	Planting Date:	Harvest population (plants/acre):
Last year:	______	________	_________	_________________
Two years ago:	______	________	_________	_________________
Three years ago:	______	________	_________	_________________

28. Enter your tillage practices for the past three years. For each year, first enter the total number of tillage operations for that year. Then, for the first tillage operation, enter the tillage code from the table below, the depth (in inches), and the date. Then enter tillage code, depth and date for the second tillage operation of that year, and so on.

Code	Tillage Method
1	No-till
2	Till-plant, or ridge plant
3	Chisel plow, or disk then chisel plow
4	Moldboard plow
5	Disc, large plowing type, or offset disc, with large (26 inch) blades
6	Disc, with 22 inch blades
7	Field cultivator
8	Springtooth
9	Drag
10	Lelly Roterra
11	Soil Finisher
12	Rotary tiller
13	Subsoiler

For example, if last year your tillage was moldboard plow in the fall, and disc in the spring, you would enter:

Number of tillage operations last year:
2
Enter method, depth and date for 1st tillage operation:
4 12 10/1/80
Enter method, depth and date for 2nd tillage operation:
5 6 5/4/81

Now enter your tillage practices:

Number of tillage operations last year:____________________

Enter the method, depth and date for these tillage operations:

Method:	Depth:	Date:
________	________	________________
________	________	________________
________	________	________________
________	________	________________
________	________	________________

Number of tillage operations two years ago: ______________

Enter the method, depth and date for these tillage operations:

Method:	Depth:	Date:
________	________	______________________
________	________	______________________
________	________	______________________
________	________	______________________
________	________	______________________

Number of tillage operations three years ago: ______________

Enter the method, depth and date for these tillage operations:

Method:	Depth:	Date:
________	________	______________________
________	________	______________________
________	________	______________________
________	________	______________________
________	________	______________________

29. Enter your fertilizer applied for the past three years:

For each year, first enter the total number of times you fertilized. Then for each fertilizer application enter the codes from the tables below for the method of application and type of fertilizer, enter the rate of application, enter the N-P-K values of the fertilizer, and enter the date of application.

Application Methods

Code	Method
1	Surface - Broadcast
2	Surface - band
3	Injected
4	Incorporated - broadcast
5	Incoporated - band
6	Sidedressed
7	Starter (with planter)
8	In irrigation water

Fertilizer Types

Code	Type
1	Anhydrous ammonia (NH_3)
2	Ammonium Nitrate (NH_4NO_3)
3	Urea
4	Nitrogen (Liquid)
5	Phosphate (P205)
6	Potash (K20)
7	Bulk N-P-K
8	Lime
9	Manure (55-77 pct. water)
10	Manure (71-85 pct. water)
11	Manure (86-99 pct. water)

For example, if last year you broadcast 300 lbs/A of potash on April 13, and broadcast 300 lbs/A of urea on April 18, and applied 150 lbs/A of 10-26-26 bulk fertilizer as starter when you planted on April 28, then you would enter:

Number of fertilizer applications last calendar year:

? 3

Method:	Type:	Rate:	N-P-K:	Date:
? 1	6	300	0-0-60	4/13/81
? 1	3	300	42-0-0	4/18/81
? 7	7	150	10-26-26	4/28/81

Now enter your fertilizer applications:

Number of fertilizer applications last calendar year: __________

Method	Type:	Rate:	N-P-K:	Date:
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______

Number of fertilizer applications two years ago: ____________

Method	Type:	Rate:	N-P-K:	Date:
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______

Number of fertilizer applications three years ago: ____________

Method	Type:	Rate:	N-P-K:	Date:
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______

30. Enter your crop residue management practice for the past three years. For each year, enter the code corresponding to your residue management practice:
    1. All residue removed
    2. Some residue removed
    3. No residue removed

Last year:________________Percent removed:______________

Two years ago:____________Percent removed:______________

Three years ago:__________Percent removed:______________

31. Have you used herbicides in any of the past three seasons?

    Enter "yes" or "no" ________ (If your answer is "no" skip to the next question.)

    Enter a one-line description of the situation:

____

32. Have you had a problem with weeds in any of the past three seasons?

    Enter "yes" or "no" __________ (If your answer is "no" skip to the next question.)

    Enter a one-line description of the situation:

____

33. Have you used insecticides or fungicides in any of the past three seasons?

    Enter "yes" or "no" __________ (If your answer is "no" skip to the next question.)

    Enter a one-line description of the situation:

____

34. Have you had a problem with insects or disease in any of the last three seasons?

    Enter "yes" or "no" __________ (If your answer is "no" skip to the next question.)

    Enter a one-line description of the situation:

____

35. Have you had drainage problems in any of the last three seasons?

    Enter "yes" or "no" __________ (If your answer is "no" skip to the next question.)

    Enter a one-line description of the situation:

____

36. Have you irrigated in any of the past three seasons?

    Enter "yes" or "no" __________ (If your answer is "no" skip to the next question.)

    Enter a one-line description of the situation:

____

Begin section on seasonal recommendations

37. Enter the type of recommendations you want (you may enter more than one)
    - 1 = tillage recommendations
    - 2 = fertilizer recommendations
    - 3 = crop residue management recommendations
    - 4 = planting date
    - 5 = "post-mortem" (analysis of past season)

X__________________

38. If you are running a "post-mortem" analysis, enter your harvest date. (Example: 9/20/84), otherwise press "CR"

X__________________

(Some of the following questions ask about your "proposed" practices; if you are looking at the past season, read those questions as saying "practice this past season")

39. Crop type menu
    enter your crop: 1) corn
    2) soybeans
    3) small grain

X__________________

40. Enter maturity class for your corn (days):
    (Example: For 110 day corn, enter 110)

X__________________

41. Enter your proposed planting date; example: 05/01/82

X__________________

42. Enter your proposed plant population (number of plants per acre):

X__________________

43. Enter code for plant population measurement:
    - 1 = number of seed planted
    - 2 = number of plants after emergence
    - 3 = number of plants at harvest

X__________________

44. For each of your soils, enter available soil moisture at planting, in inches water per five feet of soil, or enter a code from table below:

    M) Moist soil (field capacity)
    A) Average soil water
    D) Dry soil

(Example: Pembina - 8.5 Altomont - D)

X__________ X__________ X__________ X__________

X__________ X__________ X__________ X__________

45a. Enter climate data code:

    1 = you estimate or otherwise provide values for seasonal precipitation
    2 = computer estimates precipitation for this season

X______________

If you enter "2" for question 45a, skip to question 46.

45b. Enter the code which best represents your conditions:

    1 = wet year (greater than 28 inches during May, June, July, Aug. and Sept.)
    2 = average year (22-28 inches during M,J,J,A,S)
    3 = dry year (0-22 inches during M,J,J,A,S)

or, if you wish to enter daily or monthly precipitation values for May through September, skip to 45c.

X______________ (If you enter 1-3, skip to 46) or

45c. Select the appropriate code:

    1 = Monthly precip data
    2 = Daily precip data

X______________ (If you entered 2, skip to 45e)

45d. Enter monthly precip data:

May______ June______ July______ August______ September______

45e. Enter daily precip data. Use attached data sheets.

46a. Enter air temperature data code:
1) your estimate for overall seasonal temperature is needed
2) computer estimates temperatures for this season

X__________________

46b. Enter the appropriate code:
W = warm year
A = average year
C = cool year

X__________________

47a. Do you have a recent soil test for nitrogen not previously entered into this system? Enter "yes" or "no":

X__________________

If you entered "no", skip to question 48.

47b. Enter soil test nitrogen level in lbs-N per acre:

X__________________

47c. Enter code for depth of sampling:
A = 0-2 feet
B = 0-4 feet

X__________________

48. Enter your proposed nitrogen fertilizer application (lb-N/acre)

X__________________

49. Enter your proposed tillage practice:
1 = conventional (moldboard plow + disk + drag)
2 = chisel plow
3 = no till
4 = ridge till plant
5 = disk
6 = wheel track plant
7 = till plant
8 = 'x' plant

X__________________

50. Enter percent residue cover in the area between the rows:

X__________________

51. Enter percent residue cover for the row area:

X__________________