CANADIAN THESES

THÈSES CANADIENNES

NOTICE

AVIS

Canadä

NL 339 (r 86/01)

0-315-27007-1

National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Division   Division des thèses canadiennes

Ottawa, Canada
K1A 0N4

PERMISSION TO MICROFILM — AUTORISATION DE MICROFILMER

• Please print or type – Écrire en lettres moulées ou dactylographier

Full Name of Author – Nom complet de l'auteur

NITHIANANTHAN GOVINDASAMY

Date of Birth – Date de naissance

24th NOV 1951

Country of Birth - Lieu de naissance

MALAYSIA.

Permanent Address – Résidence fixe

c/o ART LYSONS, GENERAL DELIVERY, VERMILION, ALTA

Title of Thesis -- Titre de la thèse

AN ECONOMIC ANALYSIS OF CONTINUOUS CROPPING IN THE DARK BROWN SOIL ZONE OF ALBERTA

University — Université

U of A

Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée

M Sc.

Year this degree conferred — Année d'obtention de ce grade

Fall, 1983

Name of Supervisor — Nom du directeur de thèse

Alf Petersen

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈ-QUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

Date

7th Oct 83

Signature

Nithi Govindasamy

NL-91 (4/77)

THE UNIVERSITY OF ALBERTA

An Economic Analysis of Continuous Cropping In The Dark

Brown Soil Zone of Alberta

by

$\left(\text{C}\right)$ Nithiananthan Govindasamy

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Science

IN

Agricultural Economics

Department of Rural Economy

EDMONTON, ALBERTA

Fall 1983

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR   Nithiananthan Govindasamy

TITLE OF THESIS   An   Economic   Analysis of Continuous

Cropping In The Dark Brown Soil Zone of

Alberta

DEGREE FOR WHICH THESIS WAS PRESENTED   Master of Science

YEAR THIS DEGREE GRANTED   Fall 1983

Permission is hereby granted to THE UNIVERSITY OF

ALBERTA LIBRARY to reproduce single copies of this

thesis and to lend or sell such copies for private,

scholarly or scientific research purposes only.

The author reserves other publication rights, and

neither the thesis nor extensive extracts from it may

be printed or otherwise reproduced without the author's

written permission.

(SIGNED) ....

PERMANENT ADDRESS:

C/o Art Lysons,

General Delivery,

Vermillion, Alberta

DATED 10th October, 19 83

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled An Economic Analysis of Continuous Cropping In The Dark Brown Soil Zone of Alberta submitted by Nithiananthan Govindasamy in partial fulfilment of the requirements for the degree of Master of Science in Agricultural Economics.

....
Supervisor

Date...7ᵗʰ October 1983....

Abstract

This study identifies the relative profitability and risk, at the farm level, of different cropping programs in the Dark Brown soil zone of Alberta. The problem was to determine whether it is technologically and economically feasible to reduce summerfallow acreages and thereby increase net farm incomes and Alberta's agricultural production.

The general objectives of the study were to examine the economic consequences at the farm level of increasing or decreasing summerfallow acreages and to identify the main factors affecting the farm operator's decisions on cropping program selection.

Data for the study was collected from three sources. Historical yield data was obtained from the Alberta Hail and Crop Insurance Corporation. This was supplemented with soil data obtained from the Soil Survey Branch of Agriculture Canada. A farm survey was also done to obtain production coefficients for different cropping programs.

The study employs simulation methodology and identifies twelve strategies for evaluation. The strategies are evaluated on the basis of mean-standard deviation efficiency criteria arising from expected utility theory and concepts of stochastic dominance.

Results of the crop yield analysis indicate that there are yield differences between agro-climatic zones, CLI classes and subclasses and this could be an important

consideration in the selection of cropping programs at the farm level in the Dark Brown soil zone. The analysis also suggested that stubble crop yields in the study area were relatively high and increasing , in relation to fallow crop yields. The farm survey revealed that weed control, moisture conservation and income stability are the primary reasons why farmers in the study area choose to summerfallow. Results of the case farm simulation indicate that, although continuous cropping is associated with higher payoffs, it is also more risky than less intensive cropping programs. Higher output prices do make continuous cropping more attractive but again it does not dominate other less intensive cropping programs because it is riskier.

Thus, farmers in the Dark Brown soil zone are likely to significantly reduce summerfallow acreages, only in situations where either high grain prices prevail, or where new technology such as snow management techniques, improved herbicides etc. improve the stubble – fallow yield ratio. Such a reduction however, could result in significant crop production increases at the Census Division Level.

Acknowledgements

Table of Contents

List of Tables

xii

List of Figures

I. INTRODUCTION

Canada's position in the world as a major exporter of grains and oilseeds is well known(Table 1.1). The Canadian Wheat Board has set a grain production target of 50 million tonnes by 1990, with more than 36 million tonnes destined for export. Much of the actual production of Canadian grain and oilseeds takes place in the Prairie Provinces of Alberta, Saskatchewan and Manitoba. In recent years, there has been some concern from researchers and agricultural planners alike as to whether Canada can meet its grain production and export targets in the future.

Agricultural production may increase as a result of expanding the land base, better management, more extensive adoption of existing technology and by development of new technology. A recent Canada Grains Council study estimates that of the total increase in production necessary to reach the production target of 50 million tonnes by 1990, 48.5% will have to come from summerfallow reduction, 30.2% from increasing yield and 21.3% from new land brought into production. '(Table 1.2). These estimates were arrived at after extensive analyses of long term trends in yields, seeded area, land in production and area in summerfallow. The amount of new land that might be put into production is limited(Table1.3). Projected yield increases arising out of more extensive adoption of existing technology and new technology such as use of fertilizers, high yielding

----

'G.D. Weaver et. al., *Prospects for the Prairie Grain Industry,1990*. Canada Grains Council, Nov. 1982, pp 66.

TABLE 1.1

Exports of Wheat and Wheat Flour by Principal Exporters Distribution by Quantity ('000 tonnes) and Percentage of World Trade

Crop Year	Argentina	Australia	Canada	US	EEC	Others	Total
1975 – 76	3111 (4.6%)	8072 (12.1%)	12334 (18.4%)	31669 (47.4%)	7729 (11.6%)	3953 (5.9%)	66868
1976 – 77	5584 (9.0%)	8357 (13.5%)	13434 (21.6%)	26080 (42.1%)	3912 (6.3%)	4643 (7.5%)	62010
1977 – 78	2670 (3.7%)	11144 (15.3%)	16030 (22.1%)	31538 (43.5%)	4479 (6.2%)	6677 (9.2%)	72538
1978 – 79	3307 (4.6%)	7246 (10.2%)	13081 (18.4%)	32311 (45.4%)	7349 (10.3%)	7906 (11.1%)	71200
1979 – 80	4748 (5.4%)	15364 (17.6%)	15886 (18.1%)	37198 (42.5%)	10221 (11.7%)	4063 (4.7%)	87530
1980 – 81	3932 (4.2%)	11088 (11.9%)	16259 (17.5%)	41936 (45.0%)	13000 (14.0%)	6902 (7.4%)	93117

Source: The Canadian Wheat Board Annual Report 1980/81

TABLE 1.2

Total Potential Production Increases ('000 tonnes) to 1990
by Source of Increase'

Source of Increase	Manitoba	Saskatchewan	Alberta	Total	% Increase
New Land	257.6	833.1	781.5	1872.2	21.3
Reduced Fallow	376.8	3075.2	823.0	4275.0	48.5
Improved Yields	459.0	1224.3	977.1	2660.4	30.2

'increases over production levels recorded in 1981.

Source: "Prospects for the Prairie Grain Industry, 1990."
Canada Grain Council. G.D. Weaver, M.J. Nilsson,
R.E. Turney. Nov. 1982.

TABLE 1.3

Area of Land Suitable for Arable Production ('000 hectares)

Province	Total Area Potentially Arable[1]	Area of Land Not in Production in 1982[2]			
		Class 2	Class 3	Class 4	Total
Manitoba	7,528	19	279	1,841	2,139
Saskatchewan	20,192	0	544	1,116	1,660
Alberta	20,009	0	833	7,347	8,180
Total	47,729	19	1,656	10,304	11,979

[1]Total area of CLI classes 1, 2, 3 and 4 lands in each Province.

[2]Estimated by subtracting area devoted to crops, tame hay, summerfallow and improved pasture from total CLI classes 1, 2, 3 and 4 areas in each province.

Source: "Prospects for the Prairie Grain Industry, 1990." Canada Grains Council. G.D. Weaver, M.J. Nilsson, R.E. Turney. Nov. 1982.

TABLE 1.4

Yield Improvements for Alberta (kg/hectare)

	Wheat	Oats	Barley	Flaxseed	Canola
Weighted Provincial Yield (1977-1981)	2047	2221	2524	1171	1164
Projected Yield (1990)	2209	2477	2949	1336	1411

Source: "Prospects for the Prairie Grain Industry 1990."
        Canada Grains Council. G.D. Weaver, M.J. Nilsson,
        R.E. Turney. Nov. 1982.

varieties, improved machinery and chemical weed control, may be overly optimistic(Table 1.4). Improvement of unimproved land on a large scale represents an economic and technological challenge that may be insurmountable. Thus, reduction in summerfallow acreage seems to offer the most potential for significant production increases in the coming years.

In Alberta, the Canada Grains Council projects a drop in summerfallow acreage of 967,000 acres by 1990, with the largest projected increase in production arising out of a reduction in summerfallow acreage, occuring in Census Division 5, located in the Dark Brown soil zone (Fig.1.1).

A. Background To The Problem

Summerfallow is the practice of letting land lie idle. It has been a widespread practice since 1890. Table 1.5 shows the amount of land in summerfallow in Alberta since 1911. The total area of land in summerfallow in Alberta is on the decline. Summerfallowing is a management practice that represents an early attempt by producers in semi-arid regions to deal with the problem of inadequate soil moisture. However, in recent times, its efficiency as a moisture conservation technique has been called into question by many who cite its disadvantages. Soil scientists[2] contend that the practice of summerfallowing,

---

[2]D.A. Rennie, C.F. Bentley and others have featured prominently in this debate. Some of their work is reviewed in chapter 3.

Figure 1.1

Projected Increases in Production ('000 tonnes)
Arising From Summerfallow Reduction

Alberta

9.3

Saskatchewan

Manitoba

GRAND PRAIRIE

16.3

14.4
14&13

15

12

10

11

EDMONTON

215.8

167.0

191.9

157.5

22.7

66.0

22.8

3.1

4.9

DAUPHIN
60.2

BRANDON
51.1

146.0

WINNIPEG

9

11

7

8

137.0

347.7

SASKATOON
103.9

247.1

YORKTON

222.4

170.5

REGINA
189.1

HEYBURN

110.3

106.7

8A

5B

5A

8B

6A

2B

2A

1A

9:7

231.4

127.4

53.0

36.2

SWIFT CURRENT
170.3

108.9

117.1

79.8

9B

7B

7A

4B

4A

6B

3BN

3AN

3AS

3BS

305.0

63.3

39.6

LETHBRIDGE
36.7

80.1

CALGARY
32.8

9&10

7

4

2

1

5

3

8

PROVINCIAL TOTAL = 823.0

PROVINCIAL TOTAL = 3075.2

PROVINCIAL TOTAL = 376.8

Source: Canada Grains Council projection.

TABLE 1.5

Improved Land and Summerfallow Acreage in Alberta 1911 – 1981 ('000 acres)

Year	Improved Land	Summerfallow
1911	4,352	251
1921	11,768	2,918
1931	17,749	4,547
1941	20,125	6,546
1951	22,271	6,195
1956	23,746	7,091
1961	25,289	7,450
1966	27,276	6,659
1971	28,460	7,009
1976	29,302	6,494
1981		5,150

Source: "Factors Affecting Summerfallow Acreage in Alberta."
Marvin Anderson & Associates Ltd. Environment
Council of Alberta. Aug. 1981.

regardless of the extent, is an inefficient way to conserve moisture, contributes to severe wind and water erosion coupled with nitrogen leaching and so should be discarded. Proponents of snow management argue that these and other moisture conservation techniques now available, essentially eliminate the need for fallow, if it is a management practice used to conserve soil moisture. It is generally agreed now that summerfallowing is a necessary part of a farmer's cropping program in the Brown soil zone of Alberta and not a necessity in the Black soil zone, if moisture is the limiting factor in production. For the Dark Brown soil zone however, there is as yet no clear evidence on the potential for decreasing fallow and the effects it might have on production and profitability at the farm level.

Dark Brown soils in Alberta, occur in an area that is slightly less arid than Brown soil areas, and average yearly precipitation of about 14 inches with wide variation from year to year. There are approximately 9,929,000 acres of Dark Brown soils in the province, and wheat and barley are the main crops. At the farm level, the inclusion of . summerfallow in the cropping program has been standard practice for the majority of producers and the grain fallow rotation is the most popular cropping system. However in recent years, technological improvements in tillage machinery, chemical herbicides and moisture conservation techniques, have encouraged a growing number of producers towards less and less summerfallow. This situation has

created wide ranging opinions about the relative positions of different cropping systems, with respect to profitability at the farm level. Some producers claim to be better off in the long run by continuously cropping their land, while others point out that from their experience and knowledge of the issue, the high marginal product of moisture conserved on fallow land in a low rainfall year, justifies the inclusion of summerfallow in the cropping program. The situation regarding the practice of summerfallowing is characterised by confusion and conflict. Even with increasing criticism, the majority of producers in the Dark Brown soil zone, continue to allocate large acreages to fallow annually. Weed control and moisture conservation may be important considerations in the decision to summerfallow but these factors are only a part of a number of variables in the broader issue of selection of a cropping program at the farm level.

The producer has to consider physical factors such as soil fertility, temperature and rainfall; economic factors such as input and output prices, income variability, his own risk attitudes and managerial capacity as well as sociological factors such as peer pressure, social values, tradition and status issues.

Thus it is evident that farmers have a multiple objective function within which profit is important but not the only ingredient. Similarly, farmers view risk as an important ingredient. This study intends to shed some light

on the tradeoff between profit and risk associated with different cropping programs in the Dark Brown soil zone of Alberta.

In doing so a number of questions need to be addressed.

To what extent does increasing or decreasing the acreage fallowed affect production costs and income at the farm level? Does a producer achieve greater income stability by including some fallow in his rotation? Other questions that are relevant to the issue but have been inadequately answered are such items as yield differences between stubble and fallow crops, increased costs that may be incurred due to extra fertilizer and herbicides which may be required in a no fallow or reduced fallow situation, increased machinery and labour costs, added risk and income variability and producers' beliefs and opinions regarding particular cropping systems. Farmers view these and other questions as having a bearing on the long term profit advantages or disadvantages of instituting a cropping program such as continuous cropping in the Dark Brown soil zone. In addition, status issues such as keeping one's fields clean by summerfallowing may be important to the individual producer.

The desired situation then seems to be some cropping system that maximizes returns to a producer without being inconsistent with his non-economic objectives. The gap between the desired situation and the existing situation is that this 'optimal' cropping system has not been identified.

There is insuffient knowledge on the effects at the farm level of increasing or decreasing fallow in the rotation. There is also a lack of documented information regarding the practice of continuous cropping and its resultant effects on profitability and risk at the farm level over a period of time, at various input costs and product prices.

B. The Problem

According to several studies relating to production increases, a massive reduction in summerfallow acreage is required to achieve production levels set for the 1990's. These studies have consistently neglected to mention the participatory role of the producer in achieving these production levels. Very little is known about the reasons why producers in the Dark Brown soil zone of Alberta allocate large acreages to fallow annually and what will induce them to substantially reduce this acreage. Furthermore, producers who wish to go into continuous cropping require information about the expected payoffs and risks associated with such a move. Thus, the problem is to identify the relative profitability and risk of different cropping programs in the Dark Brown soil zone of Alberta and to determine whether it is technologically and economically feasible to reduce fallow acreages and thereby increase net farm incomes and Alberta's agricultural production.

C. Objectives of the study

The general objectives of the study are to examine the economic aspects at the farm level of increasing or reducing summerfallow acreage in the Dark Brown soil zone of Alberta and to determine the main factors affecting the farm operator's decisions on cropping systems. More specifically detailed objectives of the study are as follows:

1. To analyze comparative yield data for crops on stubble and fallow in the Dark Brown soil zone, obtained from the Alberta Hail and Crop Insurance Corporation (AHCIC) and supplemented with information gleaned from interviews with producers in the study area,

2. To review the technological developments that might have a bearing on the relative profitability of different crop rotation systems,

3. To identify the key attitudinal and economic factors influencing farm operators' decisions on fallow increase or reduction and to gauge farm operators' opinions and perceptions about the advantages and disadvantages of summerfallowing and continuous cropping,

4. To prepare comparative farm budgets for typical farm operations on the Dark Brown soil zone and to assess the economic implications in terms of payoff and risk of different cropping systems,

5. To undertake sensitivity analyses so as to estimate the effects of changing key parameters, such as prices and yields, on the economic outcomes of different cropping

systems,

6. To assess the potential production response, of increasing cropping intensity in Census Division 5, of the province of Alberta.

D. Hypotheses Of The Study

The following hypotheses will be tested:

1. That continuous cropping results in higher payoffs than other less intensive cropping programs,

2. That continuous cropping is associated with greater risk than other less intensive cropping programs,

3. That higher grain and oilseed prices tend to favour continuous cropping over other less intensive cropping programs,

4. That continuous cropping requires greater investment in machinery, herbicides and fertilizers than other less intensive cropping programs,

5. That machinery replacement policies at the farm level influence the relative positions of different cropping programs.

E. Assumptions Of The Study

This study relies upon certain basic assumptions. These are

1. Crop yield data, provided by the Alberta Hail and Crop Insurance Corporation (AHCIC) and also collected from a farm survey, adequately reflect crop yields relevant for

producers in the study area,

2. Expected equity values and net farm incomes are adequate measures of payoff,

3. Farmers in general are risk averse and seek to maximize expected payoff while minimizing risk,

4. Inflation and appreciation of fixed assets is assumed to be zero so as to adequately capture the effects of changing economic variables such as output prices and yields, using simulation methodology.

Other assumptions made, including the assumptions pertaining to the crop simulation model, are included later in the study.

II. THEORETICAL CONSIDERATIONS

A. Concept of a Production Function

The study of the economics of agricultural production has been facilitated by extensive use of the concept of production functions. [3] A production function expresses the physical relationship between inputs and outputs in the production process. It basically corresponds to a production possibility set which in turn depends upon the state of technical knowledge or technology set. The production possibility set is then a subset of the technology set and placing restrictions on this technology set will generate the production possibility set. This set contains a bundle of inputs and outputs. By assumption of an upper bound and a lower bound, the production possibility set is closed which by extension implies the existence of a maximum output or profit. The existence of a lower bound discounts all possibilities of discontinuities in inputs or outputs. Also no output can be produced without inputs. The upper boundary of the production set contains the most efficient production points in the production set and the locus of these points is the production function. The assumptions of continuity of the production function and strict convexity to the origin, imply diminishing returns to use of variable inputs and precludes the existence of multiple equilibria.

----

[3]For a detailed discussion of agricultural production functions and their estimation see E. O. Heady and J. L. Dillon, **Agricultural Production Functions** 5th. ed., Iowa State University Press, Ames, Iowa. 1972.

Algebraically, the production function may be written in its implicit form as:

$$F\ (Y_1,\ Y_2,\dots\dots Y_m;\ X_1,\ X_2,\ \dots\dots X_n) = 0$$

where $X_1\dots X_n$ are different inputs that are used in producing outputs $Y_1\dots\dots Y_m$. For the purposes of analysis and estimation however, the production function is usually written explicitly with certain of the variables being held constant. i. e.

$$Y_1\ =\ f(X_1,\ X_2,\ /\ X_3,\dots.X_n\ ;\ Y_2,\dots\dots\ Y_m)$$

The concept of fixed and variable resources in production is a time-related concept. A resource is considered fixed if the quantity is not or cannot be varied during the production period while a variable resource is one which the operator is willing and able to vary during the production or decision period.

Algebraically, fixed inputs in the production process may be denoted:

$$Y\ =\ f(X_1,\ X_2,\ X_3,\ X_4,\ X_{n-1}\ /X_n)$$

where X_n is the fixed input and all other inputs are variable. This production function then describes the rate at which the fixed and variable inputs are transformed into product Y.

Agricultural production functions are highly specialized and specific to each enterprise. Consequently each farm operates on its own production function.

The estimation of production surfaces is not easily accomplished. Measurement and statistical design problems,

coupled with changing response efficiency over time makes this an arduous task. Empiricists have settled on various mathematical forms of agricultural production functions such as the Cobb-Douglas function, the Spillman function and lately the Translog production function, for investigation of particular production processes. The results obtained from such investigation however, may in all likelyhood vary from what actually takes place at the farm level.

B. Production Under Conditions of Perfect Certainty

The theory of production in a perfectly competitive environment, relies upon four critical assumptions. These assumptions are:

1. the producer possesses perfect knowledge of all input and output prices.

2. the input-output technical relationship is known with certainty.

3. all market participants exhibit the simplest form of market behaviour i.e. they are price-takers and quantity-adjusters.

4. the goal of the firm is profit maximization

Under these assumptions, a set of marginality conditions may be derived, to attain the goal of profit maximization. The general case of the short run production function for a firm with M outputs and N inputs may be written implicitly as:

$$F (y_1, \ldots y_m; x_1, \ldots x_n) = 0$$

The profit function, which is simply the total revenue minus the total cost, may then be derived from the production function and maximized subject to its constraints, i.e.

$$\text{Maximize } \Pi = \sum_{i=1}^{m} p_i y_i - \sum_{j=1}^{n} r_j x_j$$

subject to: $F(y_1, \ldots y_m; x_1, \ldots x_n) = 0$

$$y_i \geq 0 \quad i = 1, \ldots m.$$

$$x_j \geq 0 \quad j = 1, \ldots n.$$

where $\quad \Pi$ = the profit function

y_i = level of the ith output

x_j = level of the jth input

p_i = price per unit of the ith output

r_j = price per unit of the jth input

F = implicit form of production function.

In order to solve this maximization problem, a new function called the Lagrangean function is formed, which is stated thus:

$$R(y, x, \lambda) = \sum_{i=1}^{m} p_i y_i - \sum_{j=1}^{n} r_j x_j +$$

$$\lambda [F(y_1, \ldots y_m; x_1, \ldots x_n)]$$

where λ is the Lagrangean multiplier. Taking the partial derivative of this function with respect to y, x and λ , and setting these equal to zero, yields the following set of simultaneous equations:

$$\frac{\partial R}{\partial y_i} = p_i - \lambda \frac{\partial F}{\partial y_i} = 0 \quad i = 1, \ldots m.$$

$$\frac{\partial R}{\partial x_j} = r_j - \lambda \frac{\partial F}{\partial x_j} = 0 \quad j = 1, \ldots n.$$

$$\frac{\partial R}{\partial \lambda} = F(y_1, \ldots, y_m; x_1, \ldots, x_n) = 0$$

This set of simultaneous equations, when solved, will give the set of marginality conditions which must be simultaneously satisfied for profit maximization or cost minimization.

Decision Rule 1,

$$r_j = p_i \frac{\partial y_i}{\partial x_j} \quad \text{or} \quad p_i = r_j \frac{\partial x_j}{\partial y_i}$$

implies that the value of the marginal product (VMP) of any input must equal its marginal factor cost (MFC). Looking at it from the output side, this is equivalent to saying that marginal revenue (MR) must equal marginal cost (MC).

Decision Rule 2,

$$- \frac{\partial x_j}{\partial x_k} = \frac{r_k}{r_j}$$

implies that the marginal rate of input substitution between any two inputs must equal the ratio of input prices.

Decision Rule 3,

$$- \frac{\partial y_i}{\partial y_k} = \frac{P_k}{P_i}$$

implies that the marginal rate of product transformation (MRT) between any two outputs must equal the ratio of output prices.

C. The Concept of Risk and Risk Preference

The assumption of perfect certainty however, does not hold in real life decisions, which are normally made in a climate of risk and uncertainty. [*] In a farm setting, yield risk may arise from climatic factor variations, insect, weeds and plant diseases. Price risk, on the other hand arises from changes in factor and product prices which are usually beyond the farm manager's control.

There are several theories that deal with the problem of decision-making under uncertainty and many of them require knowledge of decision makers' willingness to bear risk, or stated differently, knowledge of their risk preferences.

This study employs a decision theory approach based on the theorem of expected utility. As Dillon[5] argues, although game theoretic approaches, risk discount factor adjustments and other such methods may all have their uses in specific situations,

> *... only the decision theory approach based on the
> maximization of expected utility is normatively
> coherent and logical as a basis for risky choice*

---

[*] F. H. Knight *Risk, Uncertainty and Profit* Sentry Press, New York. Jan. 1921. pp. 108-122. Knight first proposed a distinction between risk and uncertainty. He argued that events whose probability distributions can be objectively known should be labelled as "risks" and subjectively conceived distributions be called "uncertainties".
However, for the purposes of this study, this distinction is not important. Risk and uncertainty will be used interchangably to identify a decision situation which does not have a single sure outcome.
[5] J. L. Dillon *The Analysis of Response in Crop and Livestock Production.* Permagon Press. 1977. pp 103.

Bernoulli's[*] principle now more commonly known as the Expected Utility Theorem, states that a utility function exists for a decision-maker whose preferences are consistent with the axioms of ordering and transitivity, continuity and independence. This theorem provides the means for ranking of risky prospects in order of preference, the most prefered being the one with the highest expected utility. The expected utility theorem then implies that for every individual farm manager, there will exist a utility function that reflects his risk preference and a subjective probability distribution that in turn reflects his personal beliefs. Von Neuman and Morgenstern[?] present a lucid exposition of cardinal utility dealing with the problem of ranking risky alternatives. However, cardinal ranking of utility is neither prefered nor necessary. A utility function measures relative utilities and the objective of the decision-maker is to maximize expected utility.

The underlying nature of the utility function itself has been the object of intense study in recent years but will not be explored further in this study. [*]

The three possible shapes of utility functions are shown in Fig. 2.1. The properties of the utility function

----

[*]J. R. Anderson et. al **Agricultural Decision Analysis** The Iowa State University Press. 1977. pp 66
[?]Von Neuman, J., and O. Morgenstern *Theory of Games and Economic Behavior* Princeton University Press, 1947.
[*]For an excellent discussion on this topic see J. R. Anderson et. al., **Agricultural Decision Analysis**, The Iowa State University Press. 1977. A.N. Halter and G.W. Dean, **Decisions Under Uncertainity with Research Applications.** South-Western Publishing Co., Cincinnati. 1971.

Figure 2.1
Three Possible Shapes of Utility Functions

U(Y)

Risk Averse

Neutral

Risk

Risk Preferring

Y
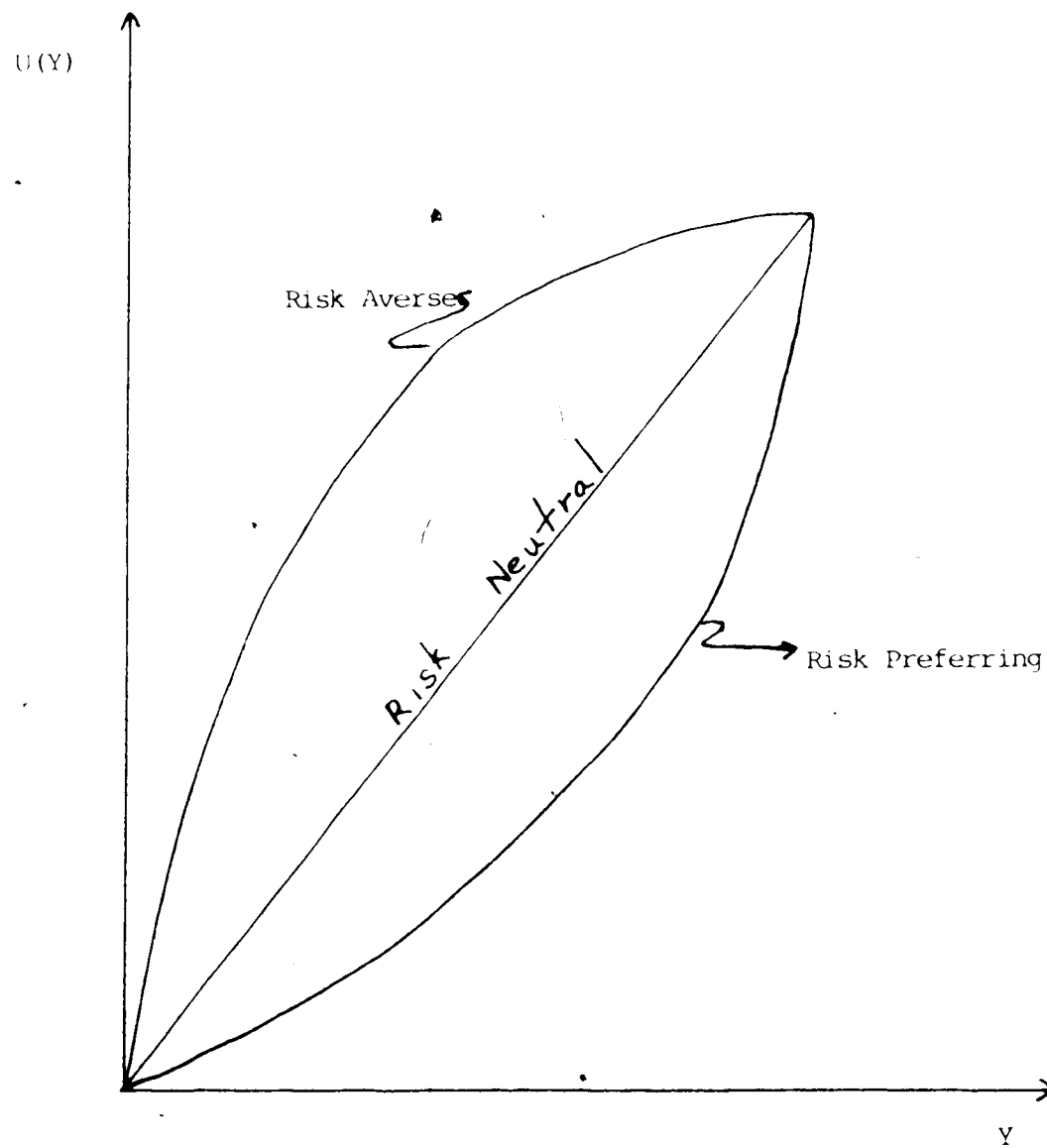
ensure that its first derivative is always positive. The second derivative however may be positive, zero or negative and it follows that the marginal utility of income will be increasing, constant or decreasing.

The classification of risk attitudes is then based upon the sign of the second derivative i.e. risk aversion is associated with a negative second derivative, risk neutrality with a zero second derivative and risk preference with a positive second derivative.

D. Mean Value-Variance (E-V) Analysis

The utility function can be mapped into expected income- variance space through a Taylor series expansion and subject to the assumption that the utility function has no higher order derivatives than the second or that the probability distribution has no higher order moments than variance. Expected utility then is a function of the mean and variance of income. The utility functions, when represented in Expected Value-Variance (E-V) space give rise to a family of indifference or iso-utility curves for the three risk categories as shown in Fig. 2.2

Bauer 'states that these indifference curves exhibit the following characterists:

    1.   "For any two alternatives, each with the same variance, the one with the higher expected income will yield the greater expected utility.
    2.   For any two alternatives, a and b, each having

'L. Bauer *A Quadratic Programming Algorithem for Deriving Efficient Farm Plans in a Risk Setting* Unpublished Phd Thesis. Oregon State University June 1971. pp. 28-30.

Figure 2.2
Indifference Curves for Three Different Risk Categories
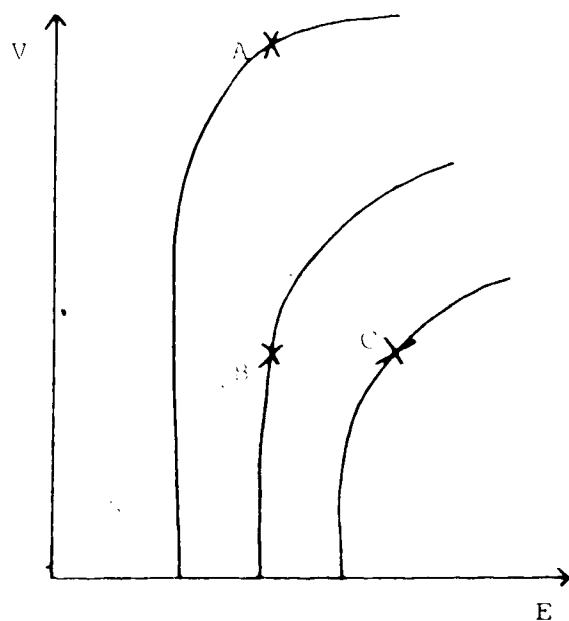
Indifference Curves for
Risk Averse Individual
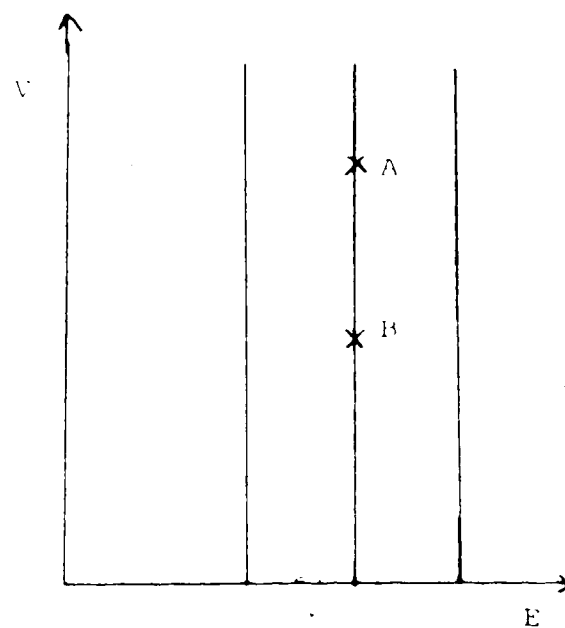
Indifference Curves for
Risk Neutral Individual
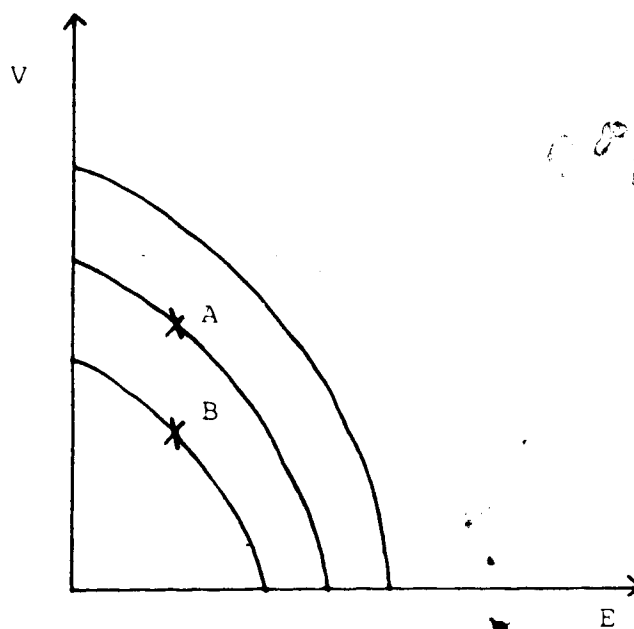
Indifference Curves for
Risk Preferring Individual

the same expected income:

a. where the marginal utility of income is
   increasing, the alternative with the greater
   variance will yield the greatest expected
   utility.   .

b. where the marginal utility of income is
   decreasing the alternative with the lower
   variance will yield the higher expected
   utility.

c. where the marginal utility of income is
   constant, both alternatives will have the
   same expected utility."

Refering to Fig. 2.2, the risk averse individual will prefer

B to A since A has a higher variance. A risk neutral

individual will be indifferent between A or B while the risk

preferring individual prefers A to B, since it has the

higher variance. This comparison of decision behavior

between individuals is not an interpersonal comparison of

utility, but merely reflects the risk preferences of

different individuals.

E. The Concept of Stochastic Dominance

The theory discussed thus far has assumed that

preferences of the individual decision-maker can be

obtained, either by direct measurement of utility functions,

experimental methods or observed economic behavior and then

quantified and used in the analysis. However, the whole area

of determining the true risk preferences of the farming

population is fraught with problems. Young ''notes that the

results of most studies dealing with risk measurement cannot

'°D. L. Young *Risk Preferences of Agricultural Producers:
Their Use in Extension and Research* Washington College of
Agricultural Research Center Scientific Paper No. 5395.
1979:

be extended to the general farming populace due to measurement and sampling limitations.

Where risk preferences are unknown, assumptions may be made about them, so that the theory of stochastic dominance can be used to rank farm plans and eliminate alternatives unacceptable to risk averse individuals. '' In this study, the farm plans or strategies, are generated by using a computer simulation model. Each generated farm plan associated with a particular cropping program will have a unique expected equity value and variance attached to it. First degree stochastic dominance (FDS) arising from the monotonic properties of the utility function previously described, asserts that for a given level of variance, more expected equity is preferred to less. With the added assumption of risk aversion, second degree stochastic dominance (SSD) asserts that for a given level of expected equity, less variance is preferred to more. The assumption of risk aversion can readily be made for the majority of farmers, while acknowledging the existence of risk preferring individuals. The risk-optimal farm plan cannot be identified without knowledge of the particular farmer's utility function. Stochastic dominance theory however relies on the identification of a set of risk-efficient strategies which are compared on the basis of entire probability distributions for each strategy, each probability

----

''J. R. Anderson, J. L. Dillon, J. B. Hardeker **Agricultural Decision Analysis**. The Iowa State University Press. Ames, Iowa. 1977.

distribution corresponding to a whole array of expected equity values. Fig.2.3 illustrates cummulative probability distributions for three strategies which when shown in E-V space illustrates the concept of first and second order stochastic dominance. Strategy B is preferred to strategy A due to first order stochastic dominance and strategy B is preferred to strategy C due to second order stochastic dominance.The locus of all risk-efficient strategies represents the efficiency frontier or boundary which locates the minimum possible variance with each possible level of expected equity (Fig. 2.4). [1][2]

---

[1][2]The set of risk-efficient strategies may be narrowed down even further if it is assumed that the third derivative of the underlying utility function is postive i.e. as people get richer, they become increasingly less averse to risk. This basically constitutes the concept of third-degree stochastic dominance (TSD). However, TSD and higher degrees of stochastic dominance require further restrictive assumptions about preference and are of interest to theorists only. In addition, it is sufficient to assume that higher moments about the mean are equal to zero and this assumption is supported by the difficulties inherent in utility measurement. E-V analysis, considering only FSD and SSD is a simple but practical way of ranking alternative strategies. Consequently, this approach is used in this study.

Figure 2.3
The Concept of First and Second
Order Stochastic Dominance
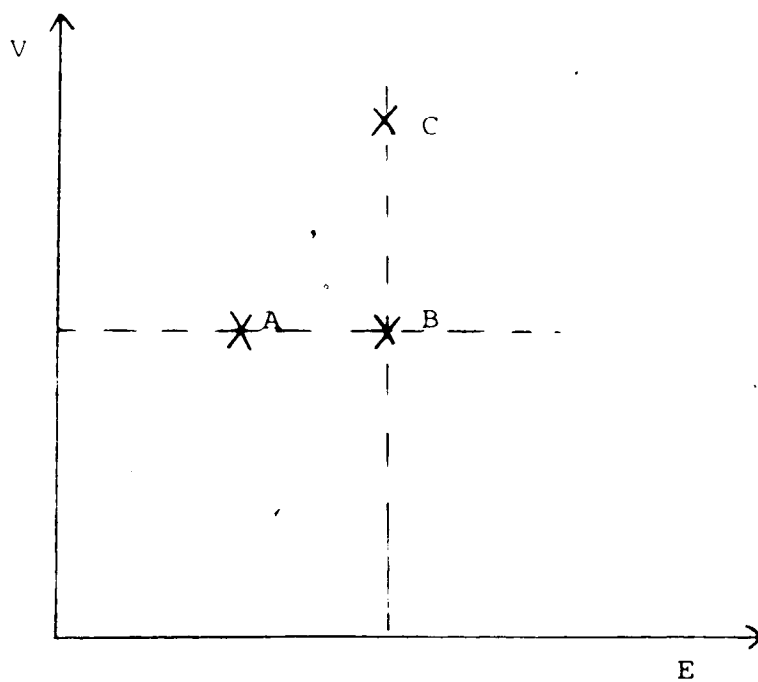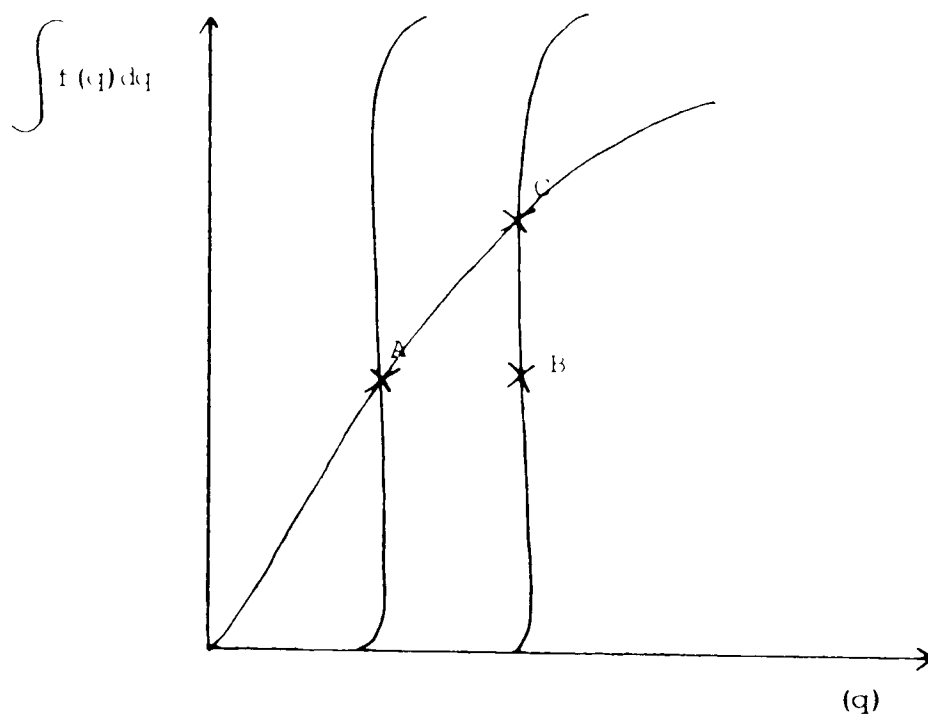
Figure 2.4
The Efficiency Frontier
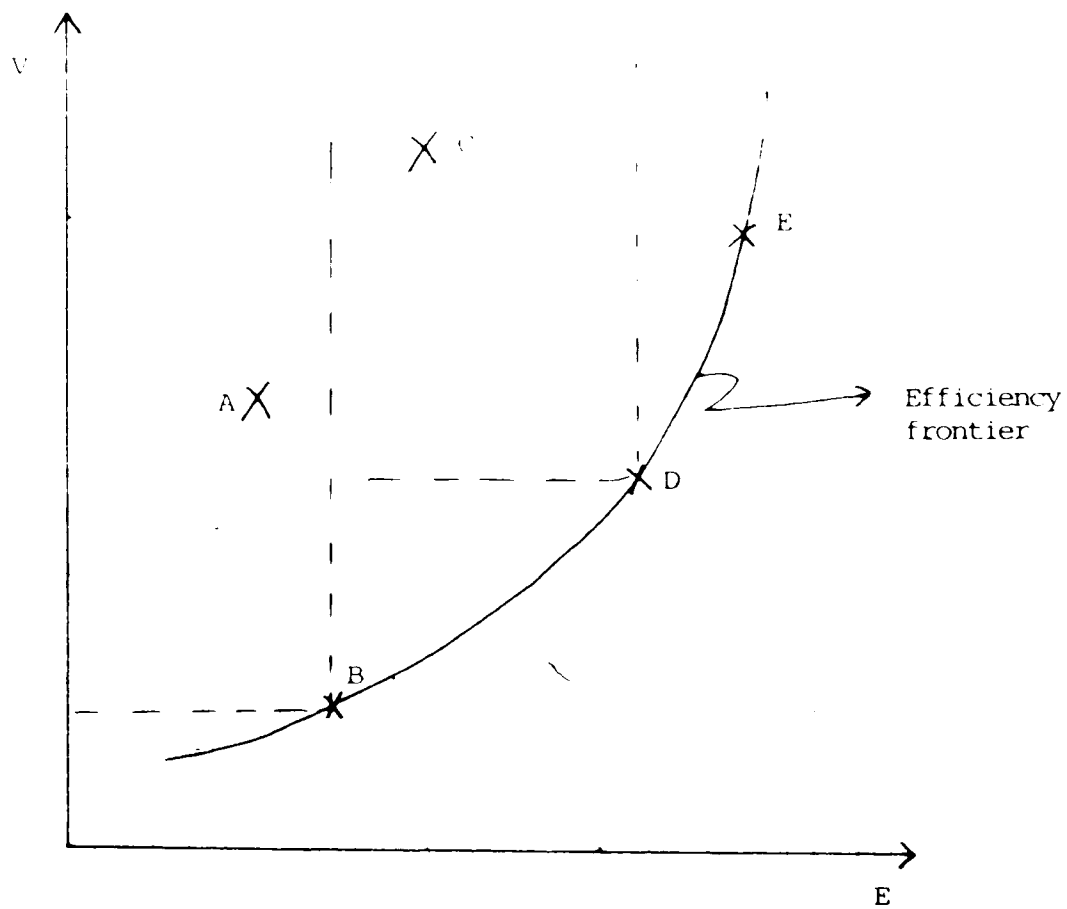
III. REVIEW OF LITERATURE

This chapter reviews the relevant literature that deals with the problem of determining relative profitability of different cropping systems. A multitude of economic, technological and physical factors impinge upon the farm manager's decision to choose some particular cropping program. Most research has concentrated upon particular aspects of the problem and this review will be appropriately divided into three sections dealing with the physical considerations, the technological developments and economic factors that have been the concern of most researchers.

A. Physical Considerations

Crop yields are influenced by a number of soil characteristics and climatic factors. Of these, soil moisture is thought to be the most limiting to plant growth in the Dark Brown soils and thus influences crop yields the most.

An analysis of 50 years of wheat yields at Swift Current, Saskatchewan by Robertson[13] determined that precipitation for the summerfallow period and for the months of May, June and August were the most important variables in explaining yield variations. Williams[14] study done for the

---

[13]Robertson, G. W., "Wheat Yields for 50 years at Swift Current, Saskatchewan in Relation to Weather." *Canadian Journal of Plant Sciences*, Vol. 54. (1974), pp 625-650.
[14]Williams, G. D. V., "Estimates of Prairie Provincial Wheat Yields Based on Precipitation and Evapotranspiration." *Canadian Journal of Plant Science*, Vol. 53. (1973), pp 17-30.

provinces of Alberta, Saskatchewan and Manitoba, (spanning a 5 year period) suggested that precipitation and potential evapotranspiration accounted for more than 80% of the yield variation in these provinces. The work of other researchers such as Bole and Pittman[15] again emphasizes the importance of soil moisture in determining yield.

A considerable amount of work has been done on the merits of summerfallowing as a weed control and moisture conservation technique. In 1967, Dew[16] reported that experiments at seven locations in Western Canada between 1956 and 1961 indicated that three or four tillage operations were usually enough for satisfactory weed control on summerfallow and generally provided highest yield of grain. Herbicides that were available at that time, were unable to give satisfactory weed control, and for those years where only herbicides were used without tillage operations, there was inadequate weed control with slightly less moisture being stored.

If moisture conservation is the prime consideration, the case against summerfallowing in the Black soil Zones is supported by the classic study of Bentley et al[17]. They found that, after 5 years of experiments using different

----

[15]Bole, J. B., and U. J. Pittman, "Springsoil Water, Precipitation and Nitrogen Fertilizer: Effect on Barley Yield." *Canadian Journal of Soil Science*, Vol. 60. (1980), pp 461-469.
[16]Dew, D. A., "Effect of Summerfallow Tillage on Soil Physical Properties and Yield of Wheat." *Canadian Journal of Soil Science*, Vol. 48 (1968), pp 21-26.
[17] See "Crop Notes", published by *United Grain Growers*, Jan. 1976, pp 100-126.

types of seeding machinery, in and around the Edmonton area, soil moisture in the spring just before seeding time was at least as good on the continuously cropped plots as on the ones that had been fallowed the preceeding year. They conclude that continuous cropping without summerfallowing in the Black Soils is desirable and practical, provided appropriate seeding equipment is available for direct seeding on stubble, effective weed control is maintained, and adequate fertilization is undertaken.

Siemens'[*] reports that there is general agreement among researchers that in drier areas such as the Brown soil zone, summerfallowing is necessary to store moisture and ensure worthwhile grain yields. A noted exception to this is Rennie'[*] who argues that summerfallowing is an inefficient way to conserve moisture, with only about 20% of the precipitation that falls during the fallow period being actually stored and available for plant growth. In addition, he argues that the costs attributed to soil erosion, soil salinity and soil nitrogen losses caused by excessive fallowing far outweighs the returns.

If the merits of summerfallowing in Brown soil zones is still being contested by researchers then in the Dark Brown soil zone, the picture is even more cloudy. The average rainfall in the Dark Brown soil zone during the growing

----

[*] Siemens, L. B., "Cropping Systems, an Evaluative Review of the Literature." *University of Manitoba Technical Bulletin #1*, 1963.
[*] See "Crop Notes", published by *United Grain Growers*, Jan. 1976, pp 100-126.

season is only between 5 and 7 inches, making reserve
moisture in the soil extremely important for plant growth.
Researchers[20] have determined that approximately 10.5 inches
of rainfall plus the water stored in the soil will give
about a 15 bushel wheat crop. Every inch above this that can
be saved will increase yields by 3 to 5 bushels until the 30
bushel mark, after which fertility and other management
factors usually become key factors.

Mackenzie's[21] work suggests that the role of
summerfallowing is not very clear-cut in the Dark Brown soil
zone. In his experiments, he found stubble yields averaged
75% of fallow yields in spite of precipitation rates well
below long term averages. However, while with the
fallow-wheat rotation, there were no crop failures in any
year, continuous wheat failed 37% of the time. This suggests
an income variability problem might exist even though
average yields seem to favour continuous cropping.

The problems created by excessive tillage of the soil
associated with the practice of summerfallowing have become
of increasing concern to soil scientists. Rennie[22] estimates
that approximately half of the organic matter content of
prairie soils has been lost during the last 70 years,

----

[20] See "Crop Notes" published by *United Grain Growers*, Oct.
1978, pp 100.100.
[21] Mackenzie, J. G., "Economics of Grain-Fallow Rotations and
Fertilizer Use in the Prairie Provinces", *Canadian Farm*
Economics Vol. 3, No. 2 (1968) pp 15-27.
[22] Rennie, D. A., "Soil, the Threatened Resource." in
Challenges and Opportunities for Saskatchewan Agriculture,
Science Council Background Study 1, Saskatchewan Science
Council, Saskatoon, 1978, pp 17-27.

forcing farmers to use more and more fertilizer to

compensate for the loss of nitrogen and other minor trace

elements. Ausenhus[23] has determined that crops grown on

fallow land take longer to mature and are more susceptible

to lodging. He believes that in the long run, producers are

better off with more intensive rotations. Bentley[24] in turn,

points out that associated with the problems of soil

salinity and erosion, declining soil nitrogen content due to

sumerfallowing is resulting in the production of grain with

lower protein content. Bentley[25] argues that the immediate

concern for prairie agriculture is to find some legume that

can suitably be accomodated into the cropping program so as

to replenish soil nitrogen levels more economically.

Penny[26] suggests that although crop yields have

increased tremendously since the early fifties, soil quality

itself has declined in the Prairies. He estimates that

organic matter levels have decreased by as much as 40% in

the Brown, Dark Brown and Black soil zones.

A study of wheat yields in the early sixties by

Michalyna and Hedlin[27]

---

[23]Ausenhus, C. 1977. "Does Summerfallow Pay?" *AGDEX* 821-6. Edmonton, Alberta Agriculture

[24] Bentley, C. F. 1977. "Agricultural Changes and Resource Endowments," *Agriculture And Forestry Bulletin* Fall 1977, pp 9-17.

[25]Bentley, C. F. "Problems and Opportunities in Western Canadian Agriculture," in *Challenges and Opportunities in Saskatchewan Agriculture*, Science Council Background Study 1, Saskatchewan Science Council, Saskatoon 1978, pp 67-74.

[26]Penny, D. C., "Agricultural Land - A Renewable Resource?" in *Farm Light and Power*, March 1980, pp 30.

[27]Michalyna, W. and R. A. Hedlin, "A Study of Moisture Storage and Nitrate Accumulation in Soil, as Related to Wheat Yields on Four Cropping Sequences", *Canadian Journal*

suggests that the primary benefit of summerfallowing may not be moisture storage but increased available nitrates to the plant, which translates itself into higher yields. This fact however, is contested by other researchers who claim that the soil quality problems created by summerfallowing cannot be ignored, even though soil nitrogen content can be increased by addition of appropriate amounts of fertilizer.

An estimate of soil erosion losses by Lindwall[28] caused by summerfallowing suggests that the losses are phenomenal. More that 20 billion tonnes of top soil are lost annually in the Prairies. Phillips et. al.[29] suggest that this loss can be controlled by minimum tillage and no-tillage types of practices. The development of such types of conservation tillage is discussed further under "Technological Developments".

The merits of summerfallowing as a weed control technique are unclear because very few studies have attached importance to economic consideration of weed control. Leavitt's[30] work seems to suggest that summerfallowing is inferior to use of herbicides to control annuals such as wild oats, but is a better method to control perennial weeds

----
[27](cont'd)*of Soil Science*, Vol. 45 (1961) pp 5-15.
[28] "Summerfallow Damaging Prairie Farmland." *The Manitoba Co-operator*, Aug. 14, 1980, pp 15; reporting on a paper by C. Wayne Lindwall, Agriculture Canada Research Station, Lethbridge, Alberta. Presented to the Canadian Society of Agricultural Engineers, Edmonton, Alberta. July 1980.
[29] R. E. Phillips et. al. "No Tillage Agriculture" *Science* 208 (4408) 1980, pp 1108-1113.
[30] Leavitt, F. D., "Research on the Control of Canada Thistle in Alberta", Prepared for the Canada Thistle Symposium, Regina, January 1980 pp 2.

such as Canada Thistle.

B. Technological Developments

Minimum Tillage

Soil quality and soil erosion problems caused by
excessive tillage and primarily associated with
summerfallowing have spawned considerable research on
conservation tillage practices. Williams[1] asserts that the
proper amount of tillage means the least tillage necessary
to produce the desired crop as efficiently as possible.
Thus, minimum tillage may include a wide variety of systems
such as strip tillage, mulch tillage, chemical fallow and
zero tillage. Zero tillage refers to the practice of
planting a crop entirely without tillage or with just
sufficient tillage to allow the placement and coverage of
the seed with soil and to allow it to germinate. Usually, no
further cultivation is done before harvesting. All
conservation tillage systems have as their objective the
maintainance of residue cover to protect the soil against
erosion and to increase water infiltration. Zero tillage
systems appear to have several advantages and disadvantages.
The possible advantages are:

1. A saving in fuel and time due to fewer field operations,
----

[1]Williams, D. A., "Tillage as a Conservation Tool", in
Tillage For Greater Crop Production Proceedings of the
American Agricultural Engineers' Conference on Crop
Production with Conservation in the 80's. Published by *The
American Society of Agricultural Engineers*, St. Joseph,
Michigan Dec. 1980

2. Maintainance of surface residue to control water and wind erosion,

3. Greater conservation of moisture in the root zone is possible than with conventional tillage as the soil will dry less,

4. Weed population may actually be reduced if the soil is disturbed less,

5. Reduced captial investment on tillage equipment and greater coverage of area per unit of time,

6. Higher retention of soil organic matter levels.

However, producers suggest a number of problems need to be solved before they will change to zero tillage. Among these are:

1. Inadequate seeding equipment to seed on hard, trashy surface,

2. Use of non-selective herbicides which are expensive,

3. More attention to detail such as timing of herbicide application,

4. May not work on certain types of soil such as fine-textured, poorly drained soils,

5. Perennial weed control may cause a problem and cost much more,

6. Increased insect and disease problems are a distinct possibility.

Use of Herbicides

Much work has been done on the merits of chemical summerfallowing, as an alternative to tillage operations. In Anderson's[1] experiments, yields obtained were similar to those for other treatments where tillage was included. More recent work at Agricultural Research Stations across the Prairies, seems to suggest that the rapid development of new and improved herbicides, is providing farmers with an alternative to conventional tillage practices. However, the biggest drawback remains the cost considerations and the fact that weather conditions must be ideal for chemical fallowing to be truly effective. Anderson found that full chemical fallow involved very high chemical costs to control all weeds and proved uneconomical.

Researchers at Lethbridge have estimated that chemical fallow could cost roughly twice as much as conventional tillage, thus requiring yields to be sufficiently high enough to make it profitable.

More recent work by Lindwall and Anderson[2] at the Agriculture Canada Research Station at Lethbridge, Alberta, suggests that, over a nine year period of testing, herbicides are as effective as tillage in controlling weeds during the summerfallow program. They also found that crop residue and soil moisture conservation were greatest when

---

[1] Anderson, C. H., "Comparison of Tillage and Chemical Summerfallow in a Semi-Arid Region", *Canadian Journal of Soil Science*. Vol. 51 pp 397-404
[2] See "Crop Notes", published by *United Grain Growers*, June 1978 pp 100.126.

weed control was achieved by chemicals alone, instead of tillage. The treatment that produced the highest yields comprised one fall tillage operation with full chemical fallow.

It has been suggested that, if summerfallowing is thought to be absolutely necessary, then the best way to do it is by a combination of mechanical tillage and chemical herbicides. By this method, soil clod size is retained, more trash remains on the surface and complete weed control is achieved. The decision to spray herbicides or cultivate, however, will depend upon soil conditions, the weeds present, stage of weed growth and soil erodibility.

Machinery Development

The development of new and more sophisticated planting machinery, primarily to seed on stubble, has also accelerated in the last five years. The objective has been to develop a practical and economical method of placing both seed and fertilizer at optimal soil depths in one field operation. The need for a device to cut plant residue has been mentioned in several studies, including those of Koronka[34] and Krall et. al.[35] Morrison and Abrams[36] consider uniform penetration of the soil and sufficient tilling in

---

[34]Koronka, P., "Machinery Development for Direct Drilling", in *Outlook Agriculture* Vol. 7, No. 4 1973. pp 190-195.
[35]Krall, et. al., "No-till Drills for Recropping". in *Montana Agricultural Experiment Station Bulletin 716*, Montana University, Bozeman, Montana.
[36]Morison, J. E., and C. F. Abrams, "Conservation Tillage Opener for Planters and Transplanters." *American Society of Agricultural Engineers*, Transcript 21. No. 4 pp 843-847.

the seed zone to obtain good seed-soil contact, as being of primary importance. Gallaher[37] considers adequate covering of the seed, proper soil forming over the seed and capability to follow the contour as essential ingredients of a good planting device.

Large and expensive zero till drills are now available commercially with some users claiming significant cost savings, with good, even seeding. However, the economic advantages of zero tillage over a period of time have yet to be reseached adequately, with most research still in its infancy. One study done at Swift Current, Saskatchewan[38] over a three year period, seems to suggest that slightly higher wheat yields are possible with zero tillage than with conventional tillage methods. However, zero tillage methods seem to work well on some soils and poorly on others. Researchers at Swift Current found that zero tillage does best on clay soils but poorly on sandy loam soils.

A somewhat similar study done at Lethbridge, Alberta,[39] compared zero tillage with conventionally tilled stubble and the results indicate that on Dark Brown soils, yields for zero tilled stubble were considerably higher than for conventionally tilled stubble.

---

[37] Gallaher, R. N., "Multiple Cropping Minimum Tillage", in *Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, Bulletin MMT-1* University of Florida, Gainseville, Florida.
[38] "Zero Tillage Does Best on Clay Soils", in *Grain News* Jan 1981.
[39] See "Crop Notes", published by *United Grain Growers* June 1978 pp 100.126.

Bentley et. al.[40] conclude that no tillage or reduced tillage generally results in satisfactory yields but not with full consistency. They find that minimum tillage may be the cause of greater year-to-year variation in yields.

In his summary of conservation tillage systems in Canada, Johnson[41] states that reduced tillage practices will improve resistance to erosion and will give satisfactory results for seeding second and subsequent stubble crops if several conditions are met. These are, that the seed is placed properly in the soil, weeds are controlled by chemical and mechanical means and sufficient fertilizer is used. If there is excess fall moisture, too heavy crop residues and specific weed problems, Johnson feels that several adjustments in tillage, fertilizer ratio etc. need to be made to ensure satisfactory results. The specific adjustments that are required for particular soil types, requires further research.

Erbach's[42] view is that, although improvements have been made in seeding equipment, satisfactory planters for conservation tillage have yet to be developed. He calls for the design and development of planters that will cut through residue, operate without blockage and that will give uniform

----

[40]See "Crop Notes", published by *United Grain Growers*, June 1978 pp 100.126.
[41]Johnson, W. E., "Conservation Tillage in Western Canada", in *Conservation Tillage: Problems and Potentials*, Soil Conservation Society of America. Special Publication No. 20.
[42]Erbach, D. C., "Planting for Crop Production with Conservation", in *Proceedings of the American Agricultural Engineers' Conference on Crop Production with Conservation in the 80's*. Published by the American Society of Agricultural Engineers, St. Joseph, Michigan, Dec. 1980.

placement and covering of seeds.

Concurring with this view, Johnson calls for additional research into methods for incorporating soil-applied herbicides without excessive soil disturbance. He also feels that research should be directed towards site-specific recommendations, rather than broad recommendations based on average data obtained under poorly defined conditions.

Snow Management

One innovative moisture conservation technique that has received increased attention from researchers and farmers alike, is snow management. Generally, snow makes up about 25% of total precipitation received, in any area. The water equivalent of snow is estimated to be one inch for every foot of snow, but to save this water for plant use means trapping and holding the snow where it is needed until it infiltrates into the ground. In the semi-arid regions of the Prairies especially, the large amount of snow that falls annually, if properly managed can be especially critical to farmers, because of its high marginal productivity in terms of increased yields.

Researchers are studying many different methods of snow management. Intermittently spaced barriers have proven to be an effective means of conserving water from snow. Stiff-stemmed plants such as tall wheatgrass, sunflowers and mustard have been used as barriers. Black and Siddoway[43]
----
[43]See "Soil, Water and Crop Production". Thorne, D. W. and M. D. Thorne, editors. 1979.

studied the effects of perennial tall wheatgrass barriers in Northern Montana. The grass, which averages about four feet in height is planted either as a single or double row, perpendicular to the prevailing winds, with the distance between plants being about thirty feet. The winter precipitation storage has been 100% greater than what was stored outside the barriers.

Ferguson and Krall[44] report that in Russia, mustard barriers are used extensively in a similar manner to tall wheatgrass. In addition, mechanically-formed snow ridges are popular in Russia, expecially in the Siberian plains where snow depth averages between 1 and 1 1/4 feet between the ridges.

A recent study conducted in Montana[45] to evaluate the differential effects of snow barriers for trapping moisture in high and low chinook frequencies, came to the following conclusions:

1. The ground freezes about 20 to 30% deeper (4 to 6 inches) in fallow fields than in fields with standing stubble. Also, soil moisture within the first 6 inches, was slightly greater during the winter, in stubble fields than in fallow fields,

2. Snow depth is greater in standing stubble fields that in

----

[44]Ferguson, H. and J. Krall, "Crop Production Systems in Arid and Semi-Arid Cool Temperate Zones", in *Soil, Water and Crop Production*, Thorne, D. W. and M. D. Thorne, editors, 1979.
[45]J. M. Caprio, et. al., "Snow Barrier Potential For Harvesting Moisture in Transects Across Chinook Areas in Montana", in *Montana Agricultural Experiment Station*, Research Report No. 175 Feb. 1982 pp 2.

fallow fields and stubble appears to be more effective

during winters with lesser amounts of precipitation,

3. The relative difference in snow depth cover from fallow

to standing stubble was greater in chinook areas that in

non-chinook areas.

The authors feel that allowing the crop stubble to

remain during the winter is one sure way of making more

moisture available for next year's crop, and it is

especially effective in dry winters.

In Canada, researchers at Swift Current,

Saskatchewan** developed a deflector shield that is

essentially mounted on the cutter bar of the swather and

enables variable height swathing. As the swather moves along

the field, the deflector bends the stalks to the side such

that only the heads and a short portion of the stalk is cut.

This method leaves a centre strip of short stubble, adjacent

to which are two parallel rows of 1 1/2 feet to 2 feet tall

stubble about 1 foot apart. The 3 to 4 inches of extra

moisture trapped represents twice as much as what was

trapped using uniform stubble. Each additional inch of soil

moisture has been shown to increase crop yields by 4 to 8

bu/acre. This finding however, is based upon a perceived

linear relationship between crop yield response and

additional amounts of soil moisture. If the actual

relationship is non-linear, and when moisture is critical,

the marginal product of that moisture is likely to be much

** R. P Zentner, Algriculture Canada Research Station, Swift
Current, Saskatchewan. Personal Communication.

higher (Fig. 3.1). This aspect of crop yield response to additional amounts of moisture is not well researched.

Another study done in Saskatchewan,[1] on farmers' fields, shows that taking measures to trap snow, such as by incorporating trash and variable height swathing, increased moisture conservation by as much as 1.8 inches, as compared to cut fields left with a uniform stubble height. Of course, the type of spring thaw and soil conditions influence the amount of snowmelt water which infiltrates into the ground or runs off, but researchers feel that variable height swathing and other snow management techniques offer the potential for exceeding the amount of moisture gained through summerfallowing.

C. Economic Considerations

The physical factors that affect crop yields have been extensively researched in the Canadian Prairies. At the same time, several economic studies have tried to determine "optimal" cropping systems, and by extension, the level of summerfallow that is desirable at the farm level. However, as Marvin Anderson[2] notes, as of 1981, no interdisciplinary study seems to have been conducted in North America to establish the quantitative importance of each of the several factors that affect selection of cropping programs.

---

[1] "Fallow Yields on Stubble", in *Country Guide* Aug. 1983 pp 38.
[2] Anderson, M. and Associates, Ltd. "Factors Affecting Summerfallow Acreage in Alberta", *Environment Council of Alberta* Publication. August, 1981.

Figure 3.1
Marginal Product of Soil Moisture
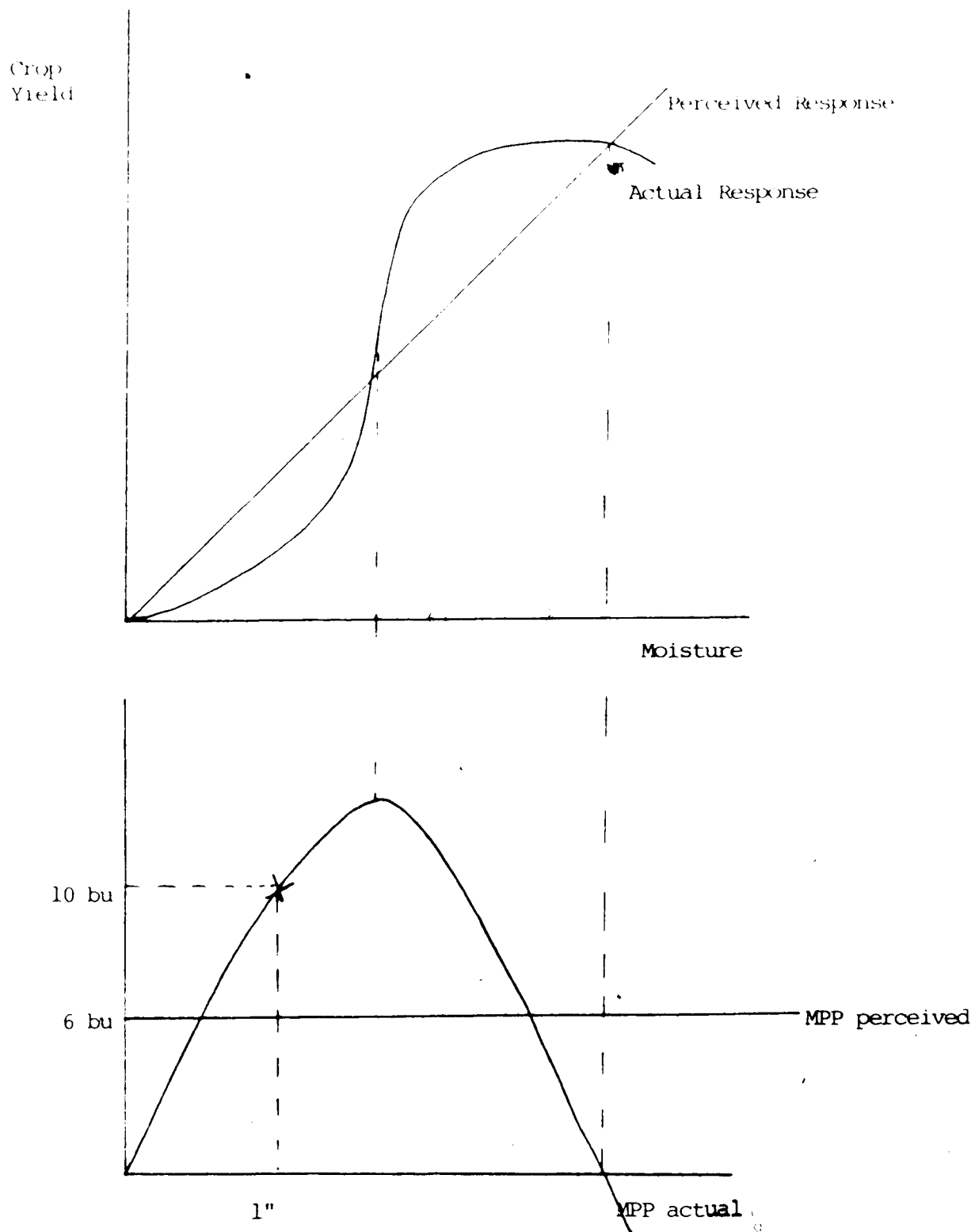
In his study, Anderson established that weed control
and moisture conservation remain the most important reasons
for summerfallow in Alberta. Furthermore, he identifies five
factors that are most likely to affect farmers' decisions
regarding selection of a cropping program. These are:

1. preseason moisture,

2. grain stocks,

3. debt/equity ratio,

4. land price input price ratio,

5. programs such as LIFT.

Ausenhus[''] first proposed the simple but useful method
of using a partial budget to determine whether summerfallow
pays (Fig.3.2). He concludes that stubble cropping requires
a greater cash outlay and involves greater risk although, he
suggests this risk can be offset by crop insurance. His
argument is that although continuous croppers will suffer
more in a poor moisture year, over the long run the gains
should offset the losses. He is quick to point out however,
that the fallow versus stubble crop controversy has no easy
solutions, and is largely a matter of individual choice.

Although several authors have mentioned the huge
economic losses possible as a result of soil salinity and
erosion caused primarily by summerfallow, no concerted
effort has been made to simultaneously quantify the returns
and losses attributed to summerfallowing.

['']Ausenhus, C., "Does Summerfallow Pay?" *AGDEX 821-6*,
Alberta Agriculture, Edmonton, March 1977.

Figure 3.2: Example of A Partial Budget

Estimated change in annual farm profits from the proposed decision to *FALLOW AN ACRE OF THIS YEAR'S CROP LAND RATHER THAN STUBBLE CROP IT*

ADVANTAGES	DISADVANTAGES
1 ADDED ANNUAL RETURNS EXPECTED	**3 ADDED ANNUAL COSTS EXPECTED**
Extra yield from fallow crop next year	Added Cost of Fallowing
70 *55* x *2.00* *30.00*	One Cultivation . *45*
Fallow Yield Stubble Yield Price	Two Rod weedings . *55*
2 REDUCED ANNUAL COSTS EXPECTED	**4 REDUCED ANNUAL RETURNS EXPECTED**
a) Stubble Crop Cash Costs	a) Stubble Crop Cash Return This Year
Seed *2 bus.* @ *3.00* *6.00*	*55* x *2.00* *110.00*
Fertilizer N *65 lb.* @ *15¢* *9.75*	Stubble Yield Price
P$_2$O$_5$ *50 lb* $^{N-48-0}$ *5.00*	
Herbicide Wild oat *AVADEX* *6.00*	b) Interest Discount On Next Year's Extra Yield
Broadleaf *1.50*	*30.00* x 10% *3.00*
Machine Costs *8.00*	
Crop Insurance *4.00*	
b) Fertilizer Saved Next Year	
65 lb actual N x *15* cents/lb *9.75*	
c) Other Chemicals Saved Next Year	
slightly less weed spray *1.00*	
TOTAL ADVANTAGES (A) $ *81.*	TOTAL DISADVANTAGES (B) $ *114*

Estimated change in Annual Farm Profits (A minus B) $ *-33*

Source: C. Ausenhus, "Does Summerfallow Pay?, AGDEX 821-6,
Alberta Agriculture, Edmonton, 1977.

Harry Hill[50] of the Prairie Farm Rehabilitation Administration, estimates that Prairie Farmers are losing as much as $400 million annually due to soil erosion and soil salinity. Rennie[51] estimates the loss from soil salinity in Saskatchewan alone at $60 million annually. However, both researchers make no mention of the possible losses to producers if no summerfallowing is practiced, because of the extra risk involved in more intensive cropping.

Several economists have concentrated their efforts on determining the economics of summerfallowing and the associated economic outcomes at farm level. Knight[52], using experiment station data from Western Kansas, determined that wheat yields, wheat prices and production costs influence the amount of fallow in a rotation to maximize return to land. Bauer[53] compared a fallow - wheat rotation and a continuous cropping rotation in North Dakota and found that where precipitation and yields are higher, continuous cropping gave higher returns. Burt and Stauber[54] used data

_____

[50]"Billions Wasted Unless Soil Saved", in *The Western Producer*, Jan 20th, 1983.
[51]Rennie, D. A., "Soil, The Threatened Resource", In *Challenges And Opportunities in Saskatchewan Agriculture*, Science Council Background Study 1, 1978, pp 17-27.
[52] Knight, D. A., "Economic Considerations for Selecting the Superior Frequency of Fallow for Wheat in Three Locations in Western Kansas", *Agricultural Experiment Station, Technical Bulletin* 85, Kansas State College, Manhattan. September 1956.
[53]Bauer, A., "Evaluation of Fallow to Increase Water Storage for Dryland Wheat Production", *North Dakota Farm Research Report* No. 25 (1968) pp 6-9.
[54]Burt, O. R. and M. S. Stauber, "Dryland Cropping Strategies to Prevent Saline Seep", *Proceedings of Regional Saline Seep Symposium, Bulletin No. 1132*, Cooperative Extension Service, Montana State University, Bozeman. April 1976.

from Montana, to conclude that farmers should use a flexible strategy based on spring soil moisture to maximize net returns. Johnson and Ali[55] examined income and risk aspects of wheat - fallow cropping systems in North Dakota and concluded that based on 1980 costs and yields, summerfallowing is becoming less desirable economically, but income variability is reduced with summerfallowing.

The economics of different cropping programs in the Canadian Prairies has received increased attention from researchers, primarily based in Agricultural Research Stations across the Prairies. Mackenzie's[56] study on grain - fallow rotations and fertilizer use done in 1968, attempted to determine whether crop yields could be maintained by reducing or eliminating fallow entirely. He makes the assumption that technological innovations in fertilizers and farming practices, may have reached a level where it is now possible to maintain or even increase yields without fallow. Using average farm prices of $1.50 for wheat, he concludes that when yields on stubble are less than 65% of fallow yields, the 1/2-1/2 cropping system will dominate in the low productive soils of the Dark Brown soil zone. However, when stubble yields are between 65% and 74% of fallow yields, then a 1/3-2/3 system or a 4 year crop-crop-crop-fallow rotation would dominate. When stubble yields are greater

----

[55]Johnson, R. G. and M. B. Ali, "Economics of Wheat - Fallow Cropping Systems in Western North Dakota" *Western Journal of Agricultural Economics,* Vol. 7, No. 1, July 1982, pp. 67-77.
[56]Mackenzie, J. G., "Economics of Grain - Fallow Rotations and Fertilizer Use in the Prairie Provinces", *Canadian Farm Economics.* Vol. 3 No. 3 Aug. 1968.

than 75% of fallow yields, then continuous cropping becomes favourable. The author feels that the practice of farmers in the Dark Brown soil zone to adopt a 1/2-1/2 or 1/3-2/3 system has been realistic given the price and yield situation and production costs.

In 1970, Mackenzie[5][7] studied crop yields in the Dark Brown soil zone and concluded that there was no evidence to support the hypothesis that yield of wheat was influenced by the crop preceeding it in the rotation. He found this to be true, whether the two crops followed one another in immediate succession or even when a year of summerfallow intervened. In 1978, Zentner and Lindwall[5][8] examined the economic feasibiltiy of using improved herbicides as an alternative to mechanical tillage in controlled experimental plots. Their results suggest that substantial savings in labour, fuel and oil, machine repairs and overhead costs are possible with zero tillage. However, they caution against blanket recommendations for widespread adoption, until much more investigation into agronomic and economic aspects of zero tillage is done. Also, this investigation should be site-specific to be worthwhile. The authors concluded that in those areas where yield advantages are high coupled with low herbicide requirements, zero tillage would seem to have greatest potential.

----

[5][7]Mackenzie, J. G., "Fallow Versus Stubble Yields",· *Canadian Journal of Plant Science* Vol 50. 1970. pp 659-666.
[5][8]Zentner, R. P. and C. W. Lindwall, "An Economic Assessment of Zero Tillage in Wheat - Fallow Rotations in Southern Alberta", *Canadian Farm Economics* Vol. 13 No. 5 Oct 1978.

In 1978 Johnson[1] assessed the net returns to land labour and management, arising out of different crop rotations in Western Canada. Comparisons of income and expenses were made for "typical" Western Canadian Farms located in all soil zones. For the Estivan-Melita area, located in the Dark Brown soil zone, the 1977 yearly net value of rotations ranged from $21.92 per acre for a fallow-wheat-oats rotation to $49.10 per acre for a fallow-rapeseed rotation. He concluded that oilseeds grown alone or in combination with cereals gave better annual returns than cereals grown alone. Also, for cereals, a three year fallow-wheat-barley rotation gave higher returns than three year rotations with oilseeds and cereal grains. This study relied extensively on secondary data and 1977 prices were used. The author points out that the absolute cost and return figures may be suspect due to the fact that 1977 prices for all grains and oilseeds were higher than the previous ten year average. Similarly, yields for most crops on stubble and fallow were also higher in 1977 than the previous ten year average.

Zentner et. al.[2] made an economic assessment of dry land cropping programs in the Canadian Prairies in 1979. The authors contend that the choice and implementation of

----

[1]Johnson, L. M., "Economic Analysis of Crop Rotations in Western Canada", *Canadian Farm Economics* Vol. 13 No. 5 Oct 1978
[2]Zentner, R. P. et. al. "An Economic Assessment of Dry Land Cropping Programs in the Prairie Provinces: Expected Net Incomes and Resource Requirements", *Canadian Farm Economics* Vol. 14 No. 4 Aug, 1979.

"optimal" cropping programs at farm level and the success of such programs depend upon the physical considerations, economic variables and the organizational abilities of the farm manager. Making the assumption that development of new technologies such as improved herbicides may have improved the competitive position of more intensive cropping programs, the authors investigated three criteria of cropping program selection. These were expected net income, seasonal resource requirements (especially labour) and income variability. Using simulation methodology, a case farm in The Dark Brown soil zone was simulated over a five year period, for different crop combinations. The authors found that the the crop combination having winter wheat on fallow and barley on stubble generally yielded highest expected net incomes. The ranking of crop combinations however, was sensitive to the price situation. With average prices, expected net income was highest for the 1/3-2/3 cropping program. With low grain prices, high fertilizer prices or high labour prices, the 1/2-1/2 cropping program was dominant. Continuous cropping was best with high grain prices, low fertilizer prices or low labour prices.

As pointed out by the authors, the results of such a study are not necessarily applicable to all farming situations because differences in resource supplies, financial positions, economic expectations and risk preferences will cause the cropping program to differ at individual farm level.

Since cropping program decisions are thought to be strongly influenced by income variability arising out of price and yield risk, the authors[1] examined differences in income variability among rotations and crop combinations. The trade-off between level and variability of expected net income was shown through expected net income calculations for specified levels of maximum income variability. The results indicate that for the Dark Brown Soil Zone, the winter wheat - fallow rotation produced the highest minimum expected net income at high levels of risk aversion and low or average grain prices. At low risk aversion levels, continuous cropping yielded the highest minimum expected net income for all prices. The authors conclude that the trade-off between expected net income, seasonality of resource requirements and income variability (risk) explains why farmers in the Dark Brown soil zone select differing crop combinations, and practice different rotations. They feel that the current cropping practices of farmers therefore, can be rationalized based on economic grounds.

Related research done by Roger Johnson[2] at North Dakota State University, suggests that summerfallowing reduces year-to-year income variability and improves stability of production and distribution of seasonal work. Johnson points out that higher wheat prices tend to favor

----

[1] Zentner, R. P. et. al., "An Economic Assessment of Dry Land Cropping Programs in the Prairie Provinces: Income Variability", *Canadian Farm Economics* Vol. 14 No. 6 Dec. 1979.
[2] "Wheat - Fallow System Sometimes Pays - North Dakota', *Grainews* Aug. 1980.

continuous cropping while on the input side, higher nitrogen prices tend to increase the value of nitrogen accumulated, making summerfallow more economical. Thus, he expects that in North Dakota summerfallow acreages will only be reduced gradually, unless crop prices spiral upwards.

Bennet's[3] work done in Saskatchewan, has determined that more intensive cropping is only feasible at high grain prices on the most productive soils. On a 1/3-2/3 rotation, and $4 per bushel for wheat, he calculates that 13.8 bushels/acre must be produced to break even. At $5 per bushel for wheat and 25 bushels/acre on summerfallow, stubble crop yield has to be 89% of fallow crop yield to break even.

Zentner et. al.[4] performed an economic analysis on the first 12 years of results of a long term rotation study in Swift Current, Saskatchewan. Under most input and product price assumptions, the 1/3-2/3 cropping program (fallow-wheat-wheat rotation) was the most profitable, although producers selecting this rotation must accept some additional yield risk or income variability. The authors feel that based on current information, Saskatchewan producers farming on Brown soils, should consider more intensive cropping. They recommend continuous cropping only

----

[3]Bennet K, "To Seed or Not to Seed Stuble?", *Grainews*, Sept. 1981.
[4]Zentner, et. al., "First 12 Years of a Long-Term Crop Rotation Study in Southwestern Saskatchewan - Economic Considerations", Contribution from Research Station, Research Branch, Agriculture Canada, Swift Current, Saskatchewan, 1983.

in periods of high expected grain prices and grain delivery
quotas. Producers who do not have the financial capability
to withstand major fluctuations in income and to purchase
additional resources, should not consider continuous
cropping. Furthermore, continuous cropping should be
accompanied with adequate crop insurance. Producers who are
highly averse to risk, should continue with the 1/2-1/2
cropping system. The authors point out that the study
ignores the long term negative effects of summerfallowing
(salinity, erosion) and its related costs. Further research
is required to estimate the full costs associated with
different crop rotations.

D. Summary and Conclusions

In summary, it would appear that most researchers,
depending upon their particular research discipline, have
concentrated on specific aspects of the problem of selection
of cropping programs. A systems simulation approach as used
by Zentner, appears to have the greatest potential to study
this problem taking into account all the relevant
biological, technical and economic variables. Short-run
studies, making dubious assumptions about input costs and
product prices are not likely to be beneficial. Similarly,
site-specific studies on the agronomic and economic aspects
of different cropping systems are sorely needed, so that
specific recommendations can be made to producers. Further
research needs to be conducted on the quantification of risk

as it relates to moving from less intensive to more intensive cropping systems.

From a societal point of view, it appears that summerfallowing is bad because it contributes to soil erosion and other soil quality problems but from the farmer's point of view, it would appear that short run economic considerations outweigh long run considerations. Institutional intervention, however, such as government programs designed to reduce risk, may induce producers to seriously consider increased cropping rates, thus reducing the long run deleterious effects of excessive summerfallowing.

IV. DATA AND METHODOLOGY

A. The Study Area

The study area in the Dark Brown soil zone is located within the Drumheller-Three Hills-Strathmore-Rockyford region of the province of Alberta. This area was chosen for study, for several reasons. The study area, located in Census Division 5, has been one of the highest wheat producing regions in the province and Census Division 5 is anticipated to have the highest potential increase in production due to reduction in summerfallow acreage, by the year 1990.[*].

Eleven farmers who are current participants of the Farm Management Field Lab Program of the Department of Rural Economy at the University of Alberta, are located in this area. [**] Over the years, these farmers have been encouraged to keep good records of their farm businesses. This particular group of farmers formed the nucleus of the study sample.

Technological change, as it affects farmers, is vividly exhibited in this region of the province and the conflicting features of different types of cropping practices are very apparent, and provided a unique opportunity for closer study. Furthermore, a research grant provided for this study

---

[*]G. D. Weaver et. al.*Prospects For The Prairie Grain Industry, 1990* Research Report, Canada Grains Council, Nov. 1982. pp 116
[**]L. Bauer et. al., "The Farm Management Field Laboratory: Its Concept and Objective and the 1980 Business Summary", *Dept. Rural Econ., U. of Alberta*, Nov. 1981, pp 7-9.

by the Alberta Research Trust Fund, emphasised the need to know more about cropping practices in this particular area of the province. In general, it was felt that this area provides a good representation of continuous cropping as practised in the Dark Brown soil zone of Alberta i.e. the zone of marginality for this particular kind of cropping program.

The study area is bounded by Townships 20 to 32 and Range 14 to 26, west of the 4th Meridian and is shown in Fig.4.1

The study area, although falling within the Dark Brown soil zone, has been divided into two Agro-climatic zones i.e. Agro-climatic zone 1 and Agro-climatic zone 2A.

The Province of Alberta has been broadly divided into six different agro-climatic zones or areas which have on the long term average, similar climatic characteristics for cropping purposes. The lines that divide Agroclimatic zones are broad transition belts. Although shown on a map as sharp definitive boundaries, they should not be interpreted as portraying sharp changes in climate from one zone to another.

Agro-climatic zone 1 denotes areas where the amount of precipitation has usually been adequate and the frost free period is considered long enough for all dryland crops in the Prairies. On the average, the frost free period is over ninety days and annual precipitation has averaged 16 to 18 inches. Agro-climatic zone 2A consists of areas where the

Figure 4.1
The Study Area
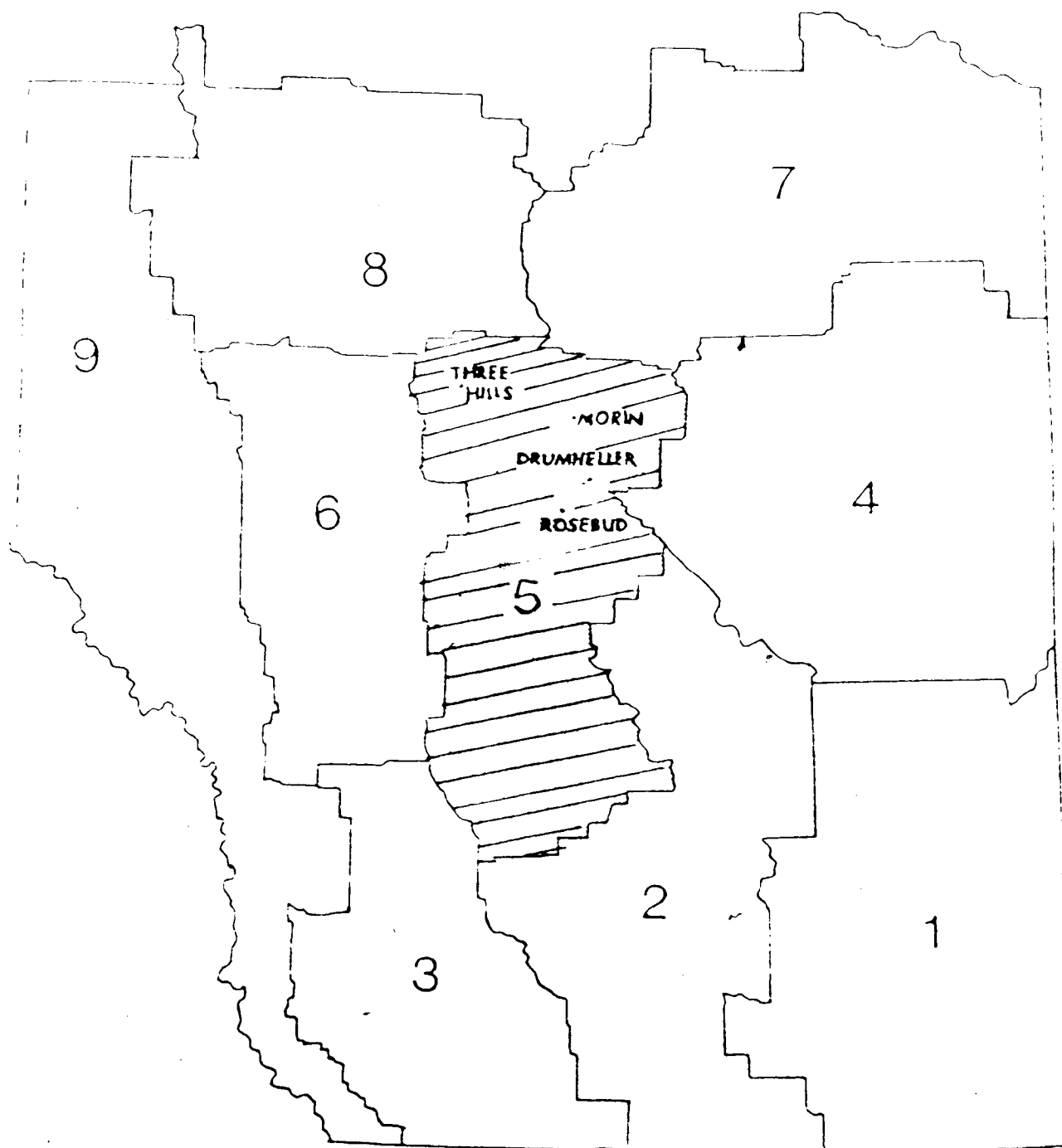
amount of precipitation, in approximately 50% of the years since weather data became available, has been a limiting factor to crop growth. The frost free period is reported to have been long enough for wheat maturity, without frost damage. Fig. 4.2 shows the Agro-climatic zones of Alberta and the location of Census Division 5. Fig 4.3 shows the study area by soil classes and subclasses.

B. Dark Brown Chernozemic Soils

Dark Brown Chernozemic Soils make up about 42,891 square miles or about 1.2% of Canada's land area. [1] They are found mainly in Alberta and Saskatchewan, forming a semi-circular belt varying from about 40 to 100 miles in width, through Central Alberta and Saskatchewan. They are bordered by the Brown and Black soil zones on the south and north respectively. Small areas of Dark Brown soils occur within the main Brown soil zone as for example in the South Eastern part of Alberta(Cypress Hills). Dark Brown soils are predominantly used for agricultural purposes with wheat being the main crop. In all, about 70% of all the Dark Brown soils are cultivated and the clay and clay loams with high moisture holding capacities, are the most productive. Coarser textured soils are known to have suffered from crop failures in very dry periods. Although Dark Brown soils are inherently fertile, moisture remains the main limitation for crop growth. Thus tillage practices have been in the main,

---

[1] J.S. Clayton et. al., "Soils of Canada" *Canada Dept. of Agric.* Vol. 1 pp 104.

Figure 4.2
Agroclimatic Zones of Alberta

63

5H(A)

5H(A)

3H(A)

3H

5H

5H

15

5H

5H

5H

2H

12
5H

5H
Grande
Prairie

3H

5H

3H

13
2H

2H

5H   14

Edmonton

10

1

5H

North

3H

9

8

Red
Deer

2A

7

6
Calgary

5

4

5N

3A

Bow

2A

3

2
Medicine
Hat

2H

Lethbridge

LEGEND

Rainfall adequate
Frost free period over 90 days

2A   Rainfall limiting factor 50% of time
for plant growth
Frost free period over 90 days

3A   Rainfall limiting factor for plant growth
Frost free period over 100 days

2H   Rainfall adequate
Frost free period 75-90 days

3H   Rainfall adequate
Frost free period 60-75 days

5H   Rainfall adequate
Frost free period less than 60 days

unc Mountain Complex
Precambrian Shield

9   Census Division

40 20 0   40   80
miles

Source: Bowser, W.E. 1967. Map compiled with the co-operation
of the Alberta Soil Survey. Ottawa: Surveys and Mapping Branch
Dept. Energy, Mines and Resources.

Figure 4.3: The Study Area by Soil Classes and Subclasses
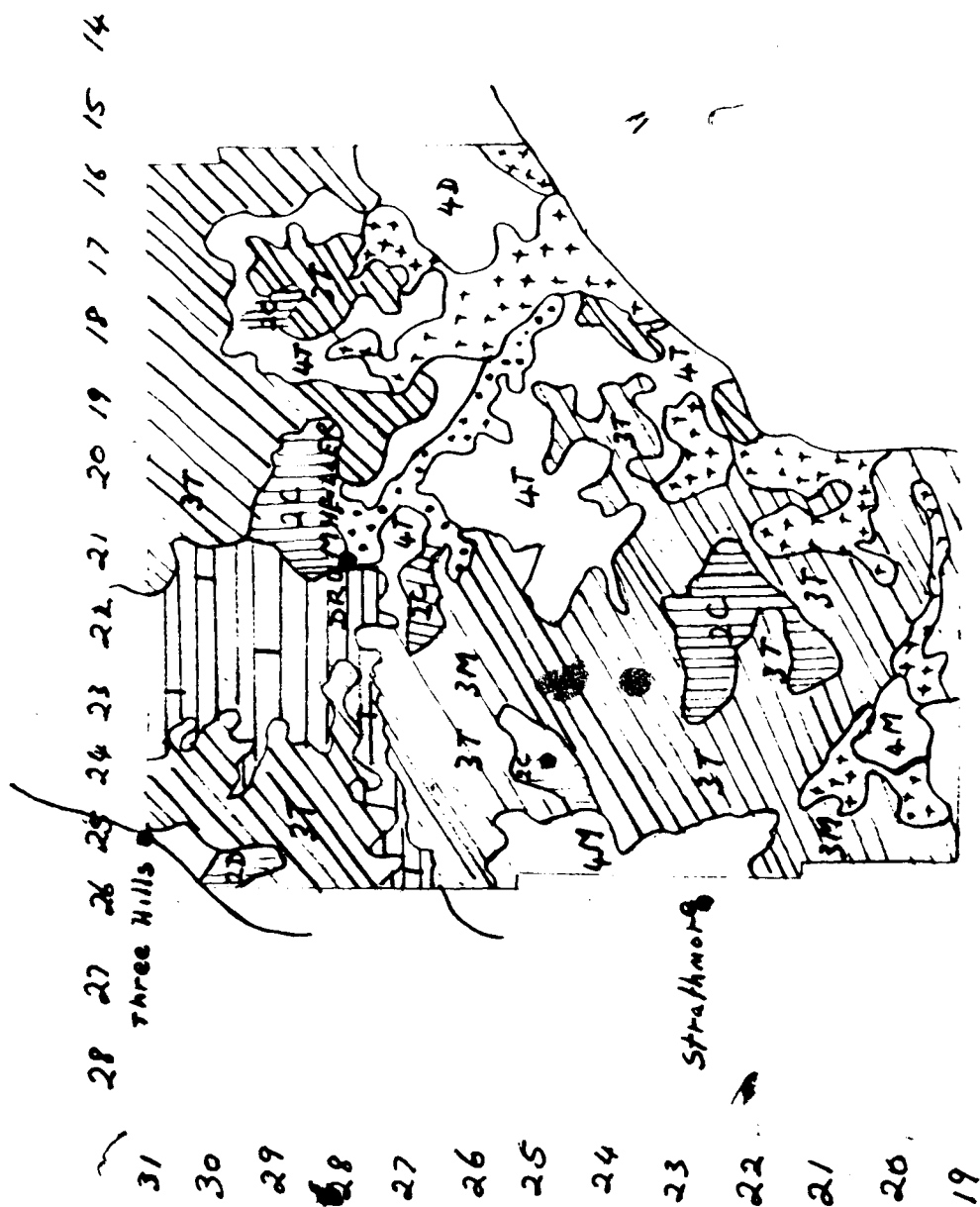
Source: G. Patterson, Soil Survey Branch, Ag. Canada, Edmonton., 1983

geared towards moisture conservation and prevention of soil erosion, with summerfallowing being a common practice.

C. Data Requirements and Limitations

Crop Yields

Expected yield differences between stubble and fallow crops and their long term variability, are thought to be of considerable importance to a producer in the Dark Brown soil zone, wishing to consider continuous cropping. Crop yields however, are influenced by soil characteristics. Soil classes are groups of soils with the same degree of limitation and soil subclasses are soils with similar limitations and hazards.

The classification of soil capability for agriculture is based upon three factors. These are the climatic, landscape and soil factors. Although crop yields have traditionally not been important in soil classification per se, they were one of the factors implicitly considered, and from the viewpoint of the producer, are all important.

With the advent of the crop insurance program in 1964, the Alberta Hail And Crop Insurance Corporation (AHCIC) has been recording yield data for grains and oilseeds, in all risk areas of the province. This data, for the study area, was provided in the form of a computer tape. Only spring wheat, barley and rapeseed are considered in this study, as these are the predominant crops grown in the area. Yields

were made available for the three crops on stubble,
fertilized stubble, fallow and fertilized fallow. The
advantage of using AHCIC data for yield analysis was that
all observations on yield were made by legal location.
Information on soils for the study area, by legal location,
was made available by the Soil Survey Section of Agriculture
Canada, Edmonton Branch. Only the yields for the ten year
period 1972-1981 are considered in this study as it was felt
that only in the last decade or so, has rapid technological
change become an important factor affecting relative
positions of different cropping programs. Furthermore,
producers in the area are likely to be more interested in
yield relationships of stubble and fallow crops of the last
few years, rather than historical yield trends.

One limitation of using AHCIC yield data is immediately
obvious. These crop yields are farmer reported estimates and
not measured yields. However, at the time of study, they
were the best available and most conveniently obtained in a
form that permited rigorous analysis, for the purposes of
this study. Although the analysis of data was done at
considerable computing costs, the task itself was
facilitated due to the compiling and coding that had been
done with part of the data, for an earlier study.[*]

The compiling had been done according to the following
procedures:

----

[*] Peters,T.W. and W.W.Pettapiece, "Crop Yields in Alberta:
Preliminary Relationships to Soil Capability for Agriculture
and Soil Type",*Alberta Institute Of Pedology, Contribution
No. M-81-1, 1981.*

1. Agro-climate: assigned by plotting the yield locations
   on the 1:2,500,000 map of Agroclimatic areas of Alberta.

2. Soil capability for agriculture classification was
   determined by the 1:250,000 Canada Land Inventory
   Series.

3. Only the Dark Brown soil zone was considered in this
   study and was identified by the Soil Group Map of
   Alberta shown in Fig. 4.4

Land capability parameters that were included in the study and coded accordingly were agro-climate, soil capability for agriculture, soil zone, parent material, texture and soil series. Productivity data that were available included four management types i.e. stubble fertilized and not fertilized, fallow fertilized and not fertilized for spring wheat, barley and rapeseed. The remaining variables were farmer-reported yields and the reporting year.

Although there were a total of 96,000 observations of yield on the three crops over a period of ten years, in some years there were less than 30 observations for specific management types and subclasses. Such groups with less than 30 individual yields, although analyzed and reported later, cannot be regarded as a reliable indicator for specific assessments. The procedure of analysis and the results are detailed in chapter 5.
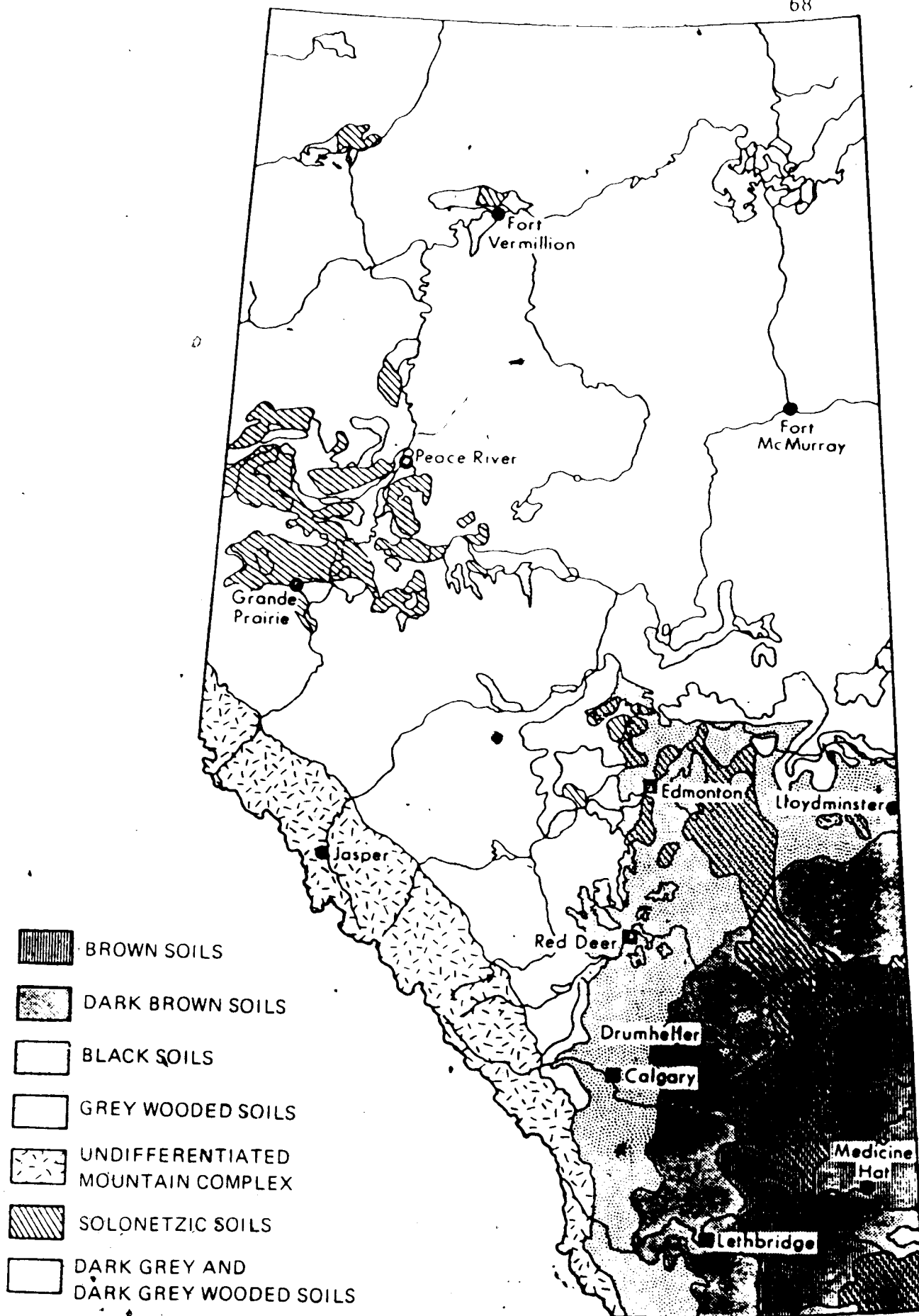
Fort
Vermillion

Fort
McMurray

Peace River

Grande
Prairie

Edmonton

Lloydminster

Jasper

Red Deer

BROWN SOILS

DARK BROWN SOILS

BLACK SOILS

GREY WOODED SOILS

UNDIFFERENTIATED
MOUNTAIN COMPLEX

SOLONETZIC SOILS

DARK GREY AND
DARK GREY WOODED SOILS

Drumheller

Calgary

Medicine
Hat

Lethbridge

Farm Survey

> *Several years ago, when a relative of mine asked me what my research involved, I explained that I was using mathematical techniques to estimate how farmers would respond to changes in Government programs, prices, and so on. Unimpressed my relative replied, "If you want to know what farmers would do, why don't you ask them?" The question has nagged me ever since.*

The above quote adequately describes the merits of doing a farm survey if the object is to determine what farmers would do given a set of changing variables. A farm survey was done for this study to determine the bio-economic processes that typically go on in commercial type operations, and to ascertain farmers' opinions and beliefs regarding different cropping programs. No attempt was made to select a random sample of farmers in the study area. Instead, some broad guidelines were established to reflect the selection of typical commercial operations with a family farm orientation. Such farmers are usually well aware of technological changes taking place in the area and generally have a tendency to be business oriented. Although the farmers selected tend to be superior managers, this is not thought to be a drawback. Indeed, the 20% of Alberta farmers who can be categorized as commercial operators, account for 80% of all agricultural production. Basically, the farms selected were:

1. between 2 and 4 sections in area

'’M. Anderson, "Factors Affecting Summerfallow Acreage in Alberta" *Environment Council of Alberta.* August 1981, pp 54.

2. commercially oriented operations with capital investment ranging from $800,000 to $1,500,000 with annual gross income from the crop sector of between $100,000 and $300,000

3. all located in the Dark Brown soil zone, clustered in the Drumheller-Three Hills- Rockyford region of the province

4. grain and oilseed producers

5. well organized, with accurate, continous information about their operations

6. broadly divisible into groups representing continuous croppers and non continous croppers.

Grain producers on Dark Brown soils, who are current participants in The Farm Management Field Lab were selected, as they fit these criteria well. In all, 22 farmers were surveyed. Time and budgetry constraints did not allow for a larger sample. It was felt that obtaining precise, continuous data from a small number of farmers, by the personal interview process, was most appropriate for this study.

The 22 farmers selected for this study, were broadly divided into three categories. The first category of farmers had 67% and less of their cultivated land under crop (group 1). The second category had greater than 67% but less than 90% of their cultivated land under crop (group 2). The third category of farmers with a cropping rate of 90% or greater were defined as being continuous croppers (group 3). Each of

the 22 sample farmers was interviewed extensively about his grain production practices and his opinions were sought on cropping systems and technological changes taking place in the study area. Appendix I contains a sample questionnaire used in this study. The results of this survey are reported and discussed in Chapter 5.

The Systems Simulation Approach

Agriculture is basically a biological system. Although it is being increasingly viewed as an economic system with supply and demand functions and dollar balances of inputs and outputs, its fundamental qualities remain biological. Problems of farm management in general and the decision making process may be studied with greater effectiveness, if the farm is viewed as a bio-economic system.

At the farm level, many different enterprises compete for the farmer's limited resource base. The complex variety of factors that affect farming and the interelationships of these factors make isolated farm planning decisions impractical. It is therefore necessary to view the process of farm planning from the point of view of the whole farm. Several mathematical programming techniques are available to aid the decision making process, in a whole farm situation.

Frequently used methods are Linear Programming (LP), Quadratic Programming (QP), Mean Absolute Deviation Approach (MOTAD), Game Theoretic Approaches and Systems Simulation. The Linear Programming approach suffers from its critical

basic assumptions of risk neutrality and linearity of objective functions and constraints. The Quadratic Risk Programming and MOTAD approaches, although superior techniques, are computationally demanding. Game-Theoretic Approaches are criticized on the grounds that they are not based on the axioms of rational choice.

Systems Simulation however, provides a means by which the complexities of the whole farm planning problem can be studied without requiring unduly restrictive assumptions. Dent and Anderson[10] define a system as: *...a complex of factors or elements that are interelated and integrate in such a way that a change in one component can affect some or all of the other components. It implies that a conceptual boundary can be erected around the complex as a limit to its identity and organizational autonomy.*

Systems simulation then refers to the development of a model that adequately represents the farm system under study, and the subsequent investigation of the behavior of the model to changes in structure and policy. The technique essentially eliminates the possibility of looking for optimal solutions, but permits the generation of efficient farm plans which may then be compared and contrasted using stochastic dominance concepts. Perhaps the most limitation of the systems simulation technique is the immense complexity of the computer models necessary to

----
[10] Dent, J.B. and J.R., Anderson **Systems Analysis in Agricultural Management** John Wiley & sons, Australasia Pty. Ltd. 1971. pp33.

represent the system under study, and the computing costs associated with generating an array of efficient plans. However, the method allows the user to perform experiments on key economic variables, and for the purposes of this study provides a means of evaluating the economic consequences of various production and managerial decisions.

D. The Dry Land Crop Enterprise Model

The Dry Land Crop Enterprise Model [1] used in this study, is a whole farm simulation model of dryland cereal and oilseed production in Western Canada. The model is a computerized, multi-period, non-optimizing, budget-generating tool. A wide array of production plans can be generated for the case farm for a ten year period. The strength of the model lies in its flexibility in allowing changes in economic variables, to accomodate differences between farms in terms of size, location, financial considerations, management characteristics, cultural practices, etc. Institutional considerations and government programs are also included to accurately portray a real life farm situation.

The model itself is made up of three components; these being a computer program, a base data file and a control data file as illustrated in Fig. 4.5. The computer program contains the mathematical relationships and

----

[1] R.P.Zentner, et. al., "A simulation Model For Dryland Crop Production In The Canadian Prairies", *Agricultural Systems*, Vol. 3, No. 4, 1978 pp. 241-257.

Figure 4.5
Components of the Simulation Model
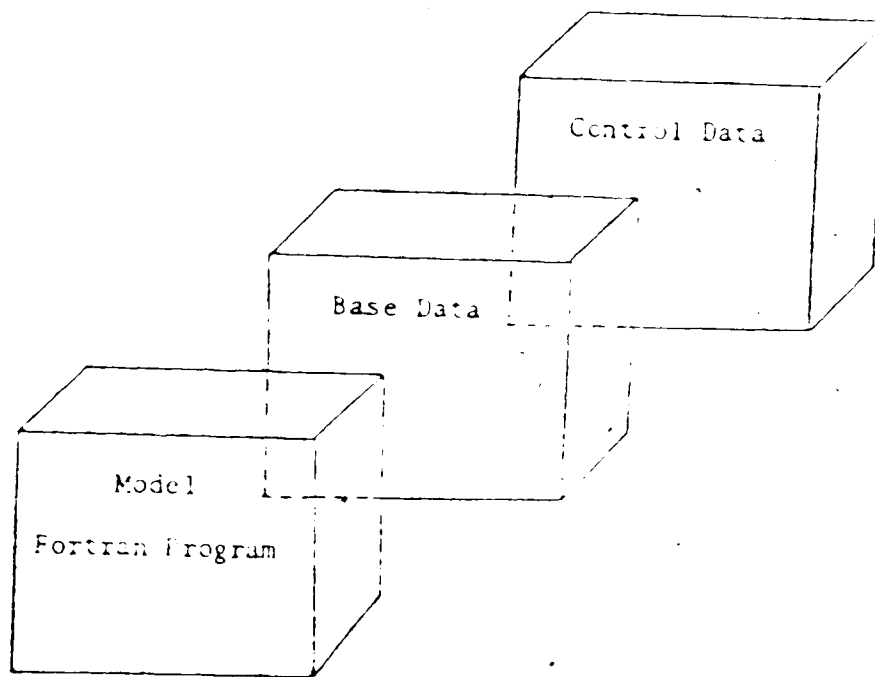
Source: R.P. Zentner, "Prairie Agricultural Farm Simulators (PAFS)", Swift Current, Saskatchewan, 1982.

interelationships of all the key biological, physical and economic processes that make up the whole farm production situation. The base data block contains all production coefficients, product prices and other economic and technical parameters for average farms in Brown, Dark Brown and Black soil zones. The control data file, which is a supplementary unit to the base data block allows the user to specify values of production and technical coefficients for the individual farm situation. The user·provides this information through an input form.

The case farm is simulated for a period of ten years through three stages. In the first stage, all information contained in the base data block and control data block are read and the model then proceeds to select a set of production alternatives which will constitute the farm plan. The second stage involves the identification of all tasks to be performed and availability of physical resources to perform these tasks. In the third stage, the model compares available resources to required resources, through a budgeting process. Stages two and three are then repeated for ten years to·complete evaluation of the plan. Several such plans are evaluated to select the "best" plan. In accordance with the objectives of the model, the "best" plan is not an optimal solution but the plan with the highest terminal net worth, from all the plans evaluated. Appendix II presents a schematic diagram of the three stages of operation.

Mode of Operation

The model is flexible enough to be operated in an optimization mode or a budget mode. The budget mode was selected for this study since farm size was to be specified and held constant for the duration of the simulation process. This was necessary to enable comparison of mean ending equities for different cropping strategies. In the budget mode, the model simply purchases or rents any resources that are limiting and gives no consideration to credit limits or resource supplies.

The Input Form

The input form allows the user to specify the following information:

1. All resources available for production,
2. Types of crops to be produced, crop management systems to be considered and operational schedules,
3. Prices paid for inputs and products,
4. Modification of production coefficients in the base data block to reflect the case farm situation.

Output Format

For each year of the planning horizon and for each production plan calculated, the following output tables are available:

1. A listing of all farm assets together with their estimated present value at the start of the year,

2. A listing of all farm assets at the end of the calendar
    year with adjustments for acquisitions and disposals,

3. A listing of all resource flows on a bi-weekly basis,

4. A bi-weekly flow of crop receipts and expenses,
    miscellaneous receipts and expenses and cash balances.

5. A listing of quantities of grain sold and prices
    received.

In addition to the above, a number of summary tables
for the ten year period are available. The first table
summarizes all physical quantities of grain produced, sold
and carried over together with labour utilized. In addition,
it contains farm financial information such as debt and
asset position, net farm income and ending equities. The
second table summarizes all receipts and expenses, changes
in inventory and details of the cropping program followed. A
more complete description of the crops produced, fertilizers
used and resulting yields appear in the third table.

E. Selection of Case Farm

The farm level simulation model of dry land crop
production described in this chapter was used to simulate a
case farm that was selected from among the 22 sample farms
surveyed. Although no statistical procedures were used in
the selection process, the case farm selected was felt to
represent the typical situation in the study area. The case
farm also exhibited the following characteristics that were
felt to be desirable for a more reliable simulation:

1. the farm manager had kept detailed records of his farm
   business for a number of years and had good records of
   prices and yields obtained,

2. at the time of study, the farm manager was practicing a
   1/2-1/2 cropping program and was considering more
   intensive cropping but wanted some idea of the economic
   consequences,

3. the farm manager was very cooperative and all production
   and financial data were made freely available.

The case farm is located about 15 miles north west of
Drumheller.

Production Information for the Case Farm

Several visits were made to the case farm to obtain
detailed production and financial information. A complete
inventory of all tillage and planting machinery, harvest
machinery, tractors, grain storage and machinery storage
facilities was identified by size and year of purchase.
Grain inventories as of Jan. 1st 1982 were obtained and land
was divided up on the basis of tenure. Acreage estimates
were made only for cultivated land used for cereal and
oilseed production. The case farm consisted of 1,100
cultivated acres with 790 owned acres and 310 acres rented
on a 1/3-2/3 crop share basis. Other assets (parts,
fertilizer and supplies, other buildings, improvements and
equipment) amounted to $50,000 and the farm had a debt load
of $40,000 at the start of simulation.

Crop Production Decision Alternatives

The model permits production under seven different rotations. However, only three different rotations are considered in this study. These are the 1/2-1/2 cropping, 1/3-2/3 cropping and continuous cropping alternatives. The crops considered for the case farm are spring wheat, barley and rapeseed with the upper limit on the proportion of cropland sown to barley and rapeseed respectively, being 20% in any one year.

Normally, spring operations start during the period between April 23rd and May 6th and this was specified accordingly in the input form. The number and type of preseed and postseed tillage and planting operations, as well as harvesting operations for stubble and fallow land were specified. The number and type of operations for the preparation of summerfallow were also included. The case farmer used a discer for planting and a machine attachment for fertilizing. Pre-emergent weed control was normally done in the fall for both stubble and fallow crops. All field operations such as swathing, combining and drying were performed by the farm manager himself with some hired help, usually during harvest. The only custom work performed involved hauling of grain to the elevator. Grain was sold both to the Canadian Wheat Board (CWB) and offboard. His crop insurance program covered all crops at 70% yield coverage with medium price coverage. He also participated in the Western Grain stabilization program.

The case farmer would consider both used and new machinery as part of his machinery purchasing policy and it was customary for him to sell his machinery at 50% maximum useful life.

All input costs related to the crop enterprise such as seed costs, weedicides, insecticides, fertilizer and fuel were specified at 1981 prices and are actual costs incurred on the farm. The case farmer valued his land at $750/acre in 1981 and this is consistent with prevailing land values for the area, at the time of study.

A minimum of $10,000/year was provided for living expenses with the added condition that consumption withdrawals will vary with net farm income such that an additional 10% will be withdrawn from net farm income in higher income years. The amount of federal income tax owing at the start of the simulation was specified along with the provincial tax rate.

New loans were to be considered for purchases of durable inputs at 18% interest rate for a ten year loan and 19% for a five year loan.

The labour supply available on the farm was calculated for each month and the calendar year divided into 26 bi-weekly periods. The present labour consists of labour supplied by the operator (10 hours/day), his family and hired labour. Additional labour, if required is paid for at $8/hour.

Modifications To The Model

Several modifications to the model were necessary for the purposes of this study. The model was originally set up to calculate crop yields in the Brown soil zone by expressing it as a function of soil texture, date of seeding, type of seeding machine used, level of spring soil moisture, level of residual soil moisture and phosphorus, applied fertilizer levels, growing season precipitation and grain losses. For the Dark Brown Soil Zone however, due to data limitations, yield is calculated as a function of applied nitrogen and phosphorous fertilizer only. For this reason, and the fact that other variables such as soil temperature may be important in yield determination, the subroutine that calculates crop yields based on biological and physical factors was suppressed, and replaced with actual crop yields obtained. The yield series used was for a ten year period (1972-1981) and was a combination of recorded case farm yields and average yields for the study area. The yield series, as shown in Table 4.1 was repeated several times and a computer program written for an earlier study enabled the generation of a series of random yields from the original ten year yield data. [72]

Similarly, the price series shown in Table 4.2 was used to generate a series of random prices. This procedure enabled the duplication of a "real world" occurance where

----

[72] B.G Monney "An Evaluation Of Farm Management Strategies Under Drought Conditions: The Case Of Dryland Grain Production On The Canadian Prairies" *Unpublished Ph.D. Thesis, University Of Alberta, June, 1983.*

TABLE 4.1

Crop Yields for Case Farm (bu/acre)

Year	Wheat		Barley		Rapeseed	
	Stubble	Fallow	Stubble	Fallow	Stubble	Fallow
1972	33.5	45	46.8	70	16.0	27.7
1973	33.6	54	47.7	75	17.2	25.0
1974	31.6	51	46.6	70	17.9	23.5
1975	40	50	45	70	18.6	23.6
1976	25	50	50	63.6	19.9	28.3
1977	35	45	35.4	70	12.5	22.4
1978	35	45	48.1	70	21.0	23.5
1979	35	45	50.8	70	18.5	22.8
1980	35	50	53.2	80	23.7	30.6
1981	30	45	56.6	80	28.4	33.4

Source: Farmer's own records, supplemented with AHCIC Crop
Yield Data for study area.

price and yields are variable. It should be pointed out that the model has the capability to calculate expected optimal levels of nitrogen (N) and phosophorous (P) fertilizer based on the levels of residual soil N and P, soil moisture at time of planting and expected price relationships, but by specifying actual yields that were obtained, this operation was circumvented. The case farmer however, was using an average of 42N and 20P for crops on stubble and 28N and 20P for crops on fallow. These rates were comparable to the fertilizer rates as recommended by soil test reports for the case farm, and were also comparable to group average rates as determined in the farm survey.

In addition to the above manipulations to the model, the information contained in the data control block was used to supplement base data information on all resource supplies and financial position and to adjust the production coefficients such that they were specific to the case farm.

Model Assumptions and Constraints

1. The model separates the land base into

   a. fallowed land,

   b. stubble land to be cropped and,

   c. stubble land to be fallowed.

   Acreage allocation of crops to be produced are made according to the following order of crop priority:

TABLE 4.2

Average Farm Level Grain Prices in Alberta ($/bu)

Crop Year	Wheat	Barley	Rapeseed	Flax
1972	1.84	1.26	3.12	3.88
1973	4.24	2.50	5.70	9.17
1974	3.96	2.20	7.08	9.24
1975	3.51	2.31	5.18	6.51
1976	2.80	1.88	6.11	6.78
1977	2.75	1.60	6.37	5.48
1978	3.66	1.72	6.32	7.29
1979	4.87	2.31	6.24	7.56
1980	5.24	2.95	6.25	8.60
1981	5.50	3.00	7.25	8.75

Source: Farm Management Data Manual, Alberta Agriculture.
       1982.

winter wheat, rapeseed, flax, spring wheat, barley and oats. Thus, crops that are to be planted are allocated first to fallowed land and then to stubble. Also, no two rotations may be followed in the same year i.e. it is not possible to have a 1/3-2/3 cropping program in one field and a continuous cropping operation on another.

2. Each stage of production can be carried out by a particular management strategy that has a specific machine complement associated with it. The model first chooses the largest machine available in the inventory to perform a specific field operation. On the other hand, the smallest tractor that is indicated in the inventory and that is capable of performing the job, is utilized first.

3. Machinery is purchased if:

    1) current machines become too old,

    2) machines in the inventory listing are not compatible with the jobs specified,

    3) machine capacity is limiting completion of a particular field operation.

If both new and used machinery are to be considered when purchasing, as is the case in this study, the model selects a purchase age between 0 and 3 years. Replacement of machines is dependent on type, age, annual use and maximum useful life. Replacement size however is determined as below:

    a) Tractors are added or replaced with a size

greater than or equal to the current largest

tractor in the inventory,

b) combines are added or replaced with one size

larger than the largest indicated in the

inventory,

c) all tractor attachments are replaced with

the largest size available that the tractor

is capable of pulling,

d) self-propelled machines, other than

combines, are replaced with the largest size

available.

4. The model does not permit deferral of purchases in a low

income year.

5. Loan payments are made once annually with equal annual

payments of principal and interest. Higher debt payments

in good income years are not permitted.

6. The quota level limitations for grain sales reflect 1982

quota level changes. Quota acreage is assigned to crops

in the same ratio as they were produced. Grain

deliveries are assumed to occur several times during the

year with equal quantities delivered each time.

7. Seasonal price cycle fluctuations that are built into

the model for grains and oilseeeds have been

circumvented by specifying grain prices.

8. Income Tax is calculated annually and paid in three

instalments. One third of the full amount is paid in the

last week of December and the remaining two thirds in

the months of February and April of the year following. There are ho "tax averaging" provisions available.

9. Machine hours and Labour hours calculations take into account time spent on field operations only and do not reflect total management time. Also, any custom work done is not taken into account in the calculation of labour utilization.

10. All technical coefficients associated with machinery use have been calculated from experimental results and available data on machinery specifications.

11. The model is not built to handle deferred grain payments.

F. Strategies Evaluated

In all, twelve different strategies were set up to be evaluated. These strategies are shown in Table 4.3 and from here on will be refered to as S_1 to S_{12}. S_1 signifies the base strategy or current situation of the farm where a 1/2 - 1/2 cropping systen is practised with no custom hire permitted, except for hauling of grain to the elevator. Consideration is given to the purchase of new and used machinges as and when required, and old machinery is sold at 50% of remaining useful life. S_1 to S_3 signify changes in machinery replacement policy for a 1/2 - 1/2 cropping system keeping all other variables constant. S_4 to S_6 signify the same changes in machinery replacement policy for a 1/3 - 2/3 cropping system. S_7 to S_9 are set up to

TABLE 4.3

Description of Strategies Evaluated

Strategy	Cropping System	Custom Hire	Machinery Replacement Policy	Purchase of Machinery		Maximum Useful Life of Machinery Sold (%)
				New	Used	
S1(BASE)	1/2-1/2	No	Yes	Yes	Yes	50
S2	1/2-1/2	No	Yes	Yes	Yes	33
S3	1/2-1/2	No	Yes	Yes	Yes	87
S4	1/3-2/3	No	Yes	Yes	Yes	50
S5	1/3-2/3	No	Yes	Yes	Yes	33
S6	1/3-2/3	No	Yes	Yes	Yes	87
S7	continuous cropping	No	Yes	Yes	Yes	50
S8	continuous cropping	No	Yes	Yes	Yes	33
S9	continuous cropping	No	Yes	Yes	Yes	87
S10	1/2-1/2	Yes	Yes	Yes	Yes	50
S11	1/3-2/3	Yes	Yes	Yes	Yes	50
S12	continuous cropping	Yes	Yes	Yes	Yes	50

examine economic consequences of changing machinery
replacement policy for a continuous cropping system. S_{10} to
S_{12} were set up to test the effect of allowing custom hire
as and when required for the three different cropping
systems. The means and standard deviations of expected
ending equities are determined for each strategy and by
stochastic dominance concepts, the dominant strategies are
identified. A comparison of labour requirements, machinery
requirements and crop input costs is made between the
dominant strategies. Price and yield sensitivity analysis
was then undertaken to determine the relative positions of
these strategies and the analysis and results are reported
and discussed in chapter 5.

V. ANALYSIS AND RESULTS

In this chapter, the analysis of data, the results and the discussion are organized into three sections. The first section deals with the analysis of yield data obtained from AHCIC. The second section comprises the qualitative analysis of data obtained from the farm survey and the third section deals with the results obtained from the computer simulation of the case farm.

A. Yield Analysis and Results of AHCIC Data

Crop Yields in Relation To Agro-climatic Areas and Management Practices

Since climate is the most limiting factor in crop growth, the yields obtained from AHCIC were first grouped according to agro-climatic zones and then by soil capability classes and sub classes. (Observations of yield made on less than 40 acres were considered as being unreliable and not considered in the analysis.) Table 5.1 indicates that there are differences in crop yields between the two agro-climatic zones. A difference of means test indicates that these differences are significant at the 5% level. Yield of wheat on fallow is 15.4% higher in agroclimatic zone 1 than in zone 2A, with yield of barley on fallow and rapeseed on fallow being 15.3% and 8.5% higher respectively. Stubble yields for wheat and barley are 9% and 7% higher in climate zone 1 than in zone 2A. A reverse trend for rapeseed

TABLE 5.1

Ten Year Average Crop Yields in bu/ac (1972-81)

	Wheat		Barley		Rapeseed	
	Stubble	Fallow	Stubble	Fallow	Stubble	Fallow
Climate	31.3	39.7	46.0	61.5	18.1	25.5
Zone 1	(10.0)	(8.2)	(14.4)	(13.5)	(8.8)	(8.5)
Climate	28.7	34.4	43	53.3	19.2	23.4
Zone 2A	(10.7)	(10.2)	(15.5)	(16.2)	(7.9)	(8.3)

( )   Figures in parentheses indicate standard deviation
        of the mean.

is observed however, where stubble yields are higher in
Agro-climatic zone 2A than in 1.

The analysis of AHCIC statistics indicates that on the
average, in agro-climatic zone 1, fertilized stubble yields
have been about 78.8% of fallow yields for wheat, 74.8% for
barley and 70.9% for rapeseed. In agro-climatic zone 2A,
they have averaged 83.4% for wheat, 80.7% for barley and
81.7% for rapeseed. These results are also significant at
the 5% level.

Crop Yields in Relation to CLI Class and Subclass

Table 5.2 illustrates a comparison of CLI capability
classes 1, 2, and 3 in climate zone 1. On the average, class
2 soils yield about 89% of class 1 soils and class 3 soils
also yield about the same as class 2 soils indicating that,
in this area, there are no marked differences in yield
between class 2 and class 3 soils. However, there are
differences between subclasses t (topography), m (moisture
stress) and d (soil structure). Subclass "t" seems to have
the least effect on yield and "d" the greatest effect. It is
also evident that 3t has higher yields than most of the
class 2 and in some cases class 1 areas too. The topography
limitation then does not appear to affect yields as greatly
as would have been expected but might be a factor in net
returns to the farmer since higher management costs may be
incurred in farming areas of steeper slopes.

TABLE 5.2

Ten Year Average Crop Yields in bu/ac (1972-81) by Soil
Class and Subclass in Agroclimatic Zone 1

Crop	Soil Class and Subclass						
	1	2t	2m	2d	3t	3m	3d
Wheat	36.3	35.0	–	35.1	36.4	35.5	
Barley	55.6	42.1	–	51.7	53.2	51.7	36.3
Rapeseed	23.0	–	–	–	25.7	–	22.5

- indicates insufficient number of observations for
analysis.

TABLE 5.3

Ten Year Average Crop Yields in bu/ac (1972-81) by Soil
Class and Subclass in Agroclimatic Zone 2A

Crop	Soil Class and Subclass								
	2c	2t	2d	3t	3d	3m	4t	4d	4m
Wheat	33.5	-	-	32.1	31.4	30.3	31.7	27.5	27.4
Barley	48.9	-	-	47.1	46.5	45.8	50.9	47.6	41.7
Rapeseed	22.0	-	-	23.3	22.8	21.9	20.7	18.2	19.4

- indicates insufficient number of observations for
analysis.

Table 5.3 compares CLI classes 2, 3 and 4 in agro-climatic zone 2A. On the average, class 4 soils yield about 90% of class 2 soils and again there appear to be no marked differences in yield between class 2 and class 3 soils. Subclass "t" has the least effect and "m" the greatest effect on yield, indicating that moisture limitation, especially on class 4 soils would be the main factor contributing to depressed yields.

Crop Yields in Relation to Fertilizer Input

Table 5.4 shows the effect of fertilizer on crop yields in agro-climatic zone 1. Yields of wheat and barley on fallow land are increased by about 8% and yield of rapeseed on fallow is increased by about 20%. On stubble land however, the effect of fertilizer is more noticeable. Wheat yields are increased by 12.5% and barley yields by about 25%.

In agro-climatic zone 2A, the effect of fertilizer on fallow yields is to increase wheat yields by about 19%, barley yields by 20% and rapeseed yields by 23%. On the stubble crop, the effect of adding fertilizer is to increase wheat yields by about 24%, barley yields by 35% and rapeseed yields by about 22% (Table 5.5). Due to data limitation no analysis was done on the amount of fertilizer applied and its effect on yield.

A detailed annual breakdown of average yields (1972-81) for both agro-climatic zones by crop management practice

TABLE 5.4

Effect of Fertilizer on Crop Yields in Agroclimatic Zone 1. Average Yields for Ten Years (1972-81)(bu/ac)

	Wheat				Barley				Rapeseed			
	Stubble		Fallow		Stubble		Fallow		Stubble		Fallow	
	NF	F	NF	F	NF	F	NF	F	NF	F	NF	F
	27.8	31.3	36.8	39.7	36.8	46.0	57.0	61.5	-	18.1	21.4	25.5
	(11.8)	(10.0)	(9.0)	(8.2)	(13.6)	(14.4)	(12.8)	(13.5)		(8.8)	(6.2)	(8.5)

( )   Figures in parentheses indicate standard deviation of the mean

--   Insufficient number of observations for analysis

NF   = Not Fertilized

F   = Fertilized

TABLE 5.5

Effect of Fertilizer on Crop Yields in Agroclimatic Zone 2A. Average Yields for Ten Years (1972-81)(bu/ac)

	Wheat				Barley				Rapeseed			
	Stubble		Fallow		Stubble		Fallow		Stubble		Fallow	
	NF	F	NF	F	NF	F	NF	F	NF	F	NF	F
	23	28.7	28.8	34.4	31.9	43	44.5	53.3	15.7	19.2	19.1	23.4
	(11.6)	(10.7)	(10.5)	(10.2)	(16.1)	(15.5)	(17.8)	(16.2)	(6.0)	(7.9)	(8.2)	(8.3)

( )   Figures in parentheses indicate standard deviation of the mean

NF   = Not Fertilized

F   = Fertilized

appears in Tables 5.6 and 5.7. An examination of these tables reveals that, although in the long run fertilized stubble yields have compared very favourably with fertilized fallow yields for the study area, they are drastically low in a poor moisture year. For example, in 1977 the average yield of fertilized stubble wheat, barley and rapeseed in climate zone 2A were only 16.5 bu/ac, 24.3 bu/ac and 12.5 bu/ac respectively.

From Table 5.8 it is not evident that stubble yields have tended to approach fallow yields in any consistent way, although from 1977 to 1981, they have averaged greater than 75% of fallow yields for all crops. In both 1976 and 1977 stubble yields on the average have been about 66% of fallow yields for all crops.

Yield Variability

TAble 5.9 and Table 5.10 show the variability of stubble and fallow yields for the period under study in agro-climatic zones 2A and 1, respectively. Generally, stubble yields have been more variable than fallow yields. On the average, fertilized stubble yields in agro-climatic zone 1 have about 47% greater variability than fertilized fallow yields. In agro-climatic zone 2A, fertilized stubble yields have been about 23% more variable than fertilized fallow yields.

TABLE 5.6

Annual Average Crop Yields in Agroclimatic Zone 2A (bu/ac)

Year	Wheat		Barley		Rapeseed	
	Stubble	Fallow	Stubble	Fallow	Stubble	Fallow
1972	27.5	35.4	45.5	55.7	16.0	22.4
1973	29.6	37.9	46.5	58.5	17.2	21.1
1974	30.2	35.0	45.6	54.0	17.9	23.9
1975	27.3	34.0	41.2	55.4	18.6	22.9
1976	22.3	37.0	33.6	55.6	19.9	24.0
1977	16.5	23.8	24.3	37.4	12.5	20.6
1978	30.0	33.6	48.3	55.6	21.0	23.5
1979	24.4	29.6	36.9	47.6	18.5	21.0
1980	33.2	36.2	53.9	57.4	23.7	28.7
1981	38.7	43.2	57.0	65.3	28.4	31.7

TABLE 5.7

Annual Average Crop Yields in Agroclimatic Zone 1 (bu/ac)

Year	Wheat		Barley		Rapeseed	
	Stubble	Fallow	Stubble	Fallow	Stubble	Fallow
1972	33.5	41.5	46.8	63.8	-	27.7
1973	33.6	43.8	47.7	65.7	-	25.1
1974	31.6	37.1	46.6	56.2	-	23.5
1975	33.6	39.8	45.8	60.3	-	23.6
1976	26.0	43.5	35.4	63.6	-	28.3
1977	22.4	37.3	34.4	60.5	-	22.4
1978	30.6	39.1	48.1	63.0	-	20.1
1979	34.2	38.4	50.8	64.8	-	22.8
1980	38.0	44.3	53.2	66.8	-	30.6
1981	37.7	44.6	56.6	70.6	-	33.4

-    indicates insufficient number of observations for analysis.

TABLE 5.8

Annual Average Stubble Yields as a % of Fallow Yields in
Agroclimatic Zone 2A (bu/ac)

Year	Wheat	Barley	Rapeseed
1972	77.6	81.7	71.4
1973	78.1	79.5	81.5
1974	86.3	84.4	74.9
1975	80.3	74.4	81.2
1976	60.3	60.4	82.9
1977	69.3	64.9	60.6
1978	89.3	86.8	89.4
1979	82.4	77.5	88.1
1980	91.7	93.9	82.6
1981	89.6	87.3	89.6

TABLE 5.9

Variability of Stubble and Fallow Yields (bu/ac) in Agroclimatic Zone 2A (1972-81)

Crop	Management Practice	Mean Yield	s.d.	c.v.
Wheat	unfertilized stubble	23.1	11.6	50
Wheat	fertilized stubble	28.7	10.7	37
Wheat	unfertilized fallow	28.8	10.5	36
Wheat	fertilized fallow	34.4	10.2	30
Barley	unfertilized stubble	31.9	16.1	50
Barley	fertilized stubble	43.0	15.5	36
Barley	unfertilized fallow	44.5	17.8	40
Barley	fertilized fallow	53.4	16.2	30
Rapeseed	fertilized stubble	19.2	7.9	41
Rapeseed	unfertilized fallow	19.1	8.2	43
Rapeseed	fertilized fallow	23.5	8.3	35

s.d.   = standard deviation

c.v.   = coefficient of variation (%)

TABLE 5.10

Variability of Stubble and Fallow Yields (bu/ac) in
Agroclimatic Zone 1 (1972-81)

Crop	Management Practice	Mean Yield	s.d.	c.v.
Wheat	unfertilized stubble	27.8	11.9	43
Wheat	fertilized stubble	31.3	10.0	32
Wheat	unfertilized fallow	36.8	9.0	25
Wheat	fertilized fallow	39.7	8.2	21
Barley	unfertilized stubble	36.8	13.7	37
Barley	fertilized stubble	46.0	14.4	31
Barley	unfertilized fallow	57.0	12.8	22
Barley	fertilized fallow	61.5	13.5	22
Rapeseed	fertilized stubble	18.1	8.8	49
Rapeseed	unfertilized fallow	21.4	6.2	29
Rapeseed	fertilized fallow	25.5	8.5	33

s.d.   = standard deviation

c.v.   = coefficient of variation (%)

B. Summary Observations

The relationship of crop yields to soil and climatic factors are emphasized in the preceeding analysis using AHCIC data. Although the analysis procedure has been more qualitative than quantitative, some general conclusions may be drawn:

1. Yields of wheat, barley and rapeseed are related to agro-climatic zones with zone 1 having higher yields than zone 2A.

2. Within any one agro-climatic zone, there seems to be a definite relationship between yields, CLI classes and subclasses. Class 2 and class 3 soils yield about 89% of class 1 soils and class 4 soils yield about 90% of class 2 soils. There does not seem to be any perceptible differences in yield between class 2 and class 3 soils in the study area. This may be due to the fact that there is a predominance of 3t soils in the study area and the "t" limitation has very little apparent effect on yields. Subclass limitations seem to affect yields differently with the topography limitation being the least serious.

3. Fertilized stubble yields, on the average have been about 78% of fertilized fallow yields for all crops in both agro-climatic zones but stubble yields are more severely affected in a low moisture year than fallow yields. As expected, stubble yields show greater variation than fallow yields and as a result, have not

tended to approach fallow yields in any consistent way, although during the period 1977-81, they have been consistently greater than 75% of fallow yields.

4. The effect of fertilizer input has been to increase fallow yields by 21% and stubble yields by 27% in climate zone 2A as compared to increases of 12% and 18% respectively in climate zone 1.

This analysis confirms certain suspicions about stubble and fallow crop yields in the study area, but also shows apparent discrepancies that otherwise would not have been expected. For example, the claim by many producers who are continuous croppers, that their stubble yields have averaged more than 75% of fallow yields with adequate fertilizer and good management, cannot be rejected too quickly. However, more sophisticated statistical tests need to be performed with the data to confidently accept or reject such claims.

There is a need to re-study the topographical limitation in the classification scheme because the "t" limitation does not seem to be a limitation at all, at least in respect to crop yields in the study area. Agricultural capability classes were not based on yields alone but as the above analysis shows, they are closely correlated. Of course, management-related factors have not been included in the analysis but would be an important considerations in agricultural capability classification. More specific conclusions about yield trends and their relationship to soil and climatic factors can only be made if several data

sources are compared and valid statistical relationships of the variables established.

C. Analysis of Sample Farms

All 22 respondents classified their operation as grain farms although 3 of them had incomes from livestock operations. The sample was divided into three categories based on percentage of cultivated land cropped as described in chapter 4. The average size of farm surveyed was 1,705 acres. Table 5.11 presents group average results for the three categories for the year 1981.

The average age of the continuous cropper is slightly less than the non-continuous cropper. The continuous croppers are also likely to be the bigger farmers and on the average have about 28% more cultivated land than non-continuous croppers. There does not seem to be any significant differences in machinery investment per cultivated acre among the three categories but these are qualitative estimates which are examined in greater detail in the third stage of analysis.

Labour was defined in man days with the assumption of a 10 hour working day in the summer and an 8 hour working day in the winter. Respondents were asked to give a breakdown of all labour utilized on the farm in 1981, which included actual number of hours spent on field operations and management time for the farm as a whole. On a per cultivated acre basis, the countinuous croppers seem to use far less

TABLE 5.11

Group Average Results, 1981 Crop Year

Item	67% or less cropped		Greater than 67% but less than 90% cropped		90% or more cropped
Number of farms	7		8		7
Average age of Operator	47.8		47.5		43.4
Cultivated Acres	1,335		1,777		2,005
Cropped Acres	846		1,395		1,924
Farm Cash Sales	$146,966		$219,312		$280,571
Machinery Investment /Cult. Acre at Cost	$134		$139		$138
Labour Utilization in Man Days /Cult. Acre	0.347		0.235		0.196
	St.	Fal.	St.	Fal.	St.
Fertilizer input /seeded acre (lbs)	44.5N 22P	27.5N 21.7P	47.4N 31.6P	23N 27P	54N 31P
Fertilizer Cost /crop acre in stubble	$21.60		$24.30		$27.30
Fertilizer Cost /crop acre in fallow	$15.50		$16.50		
Herbicide Cost /crop acre	$8.88		$14.43		$15.50

St. = stubble

Fal. = fallow

labour than the other two categories. Again this result will be examined more closely in the third stage of analysis.

Continuous croppers tend to use more nitrogen fertilizer on their stubble crop than the non-continuous croppers, with correspondingly greater fertilizer costs per crop acre. Also, chemical costs are about twice as much for the continuous cropper as compared to those with 67% or less of their land cropped.

Crop Yields

Average crop yields obtained in 1981 are shown in Table 5.12. Continuous croppers in the sample reported getting about 88% of fallow yields for wheat on stubble. Farmers in Group 1 reported getting about 79% of fallow yields for wheat on stubble and about 78% for barley on stubble.

Farmers in Group 2 reported that they obtained about 72% of fallow yields for wheat on stubble. A comparison of stubble yields for the three groups reveals that continuous croppers seem to be getting 24% higher yields for wheat on stubble and about 32% higher yields for barley on stubble than the other two groups. Furthermore, the yields obtained by continuous croppers for wheat, barley and rapeseed on stubble were about 94%, 92% and 65% respectively of the yields obtained by the non-continuous croppers on their fallow land.

Table 5.13 presents group average yields for the 5 year period, 1977-81. During this period, continuous croppers

TABLE 5.12

Group Average Crop Yields, 1981 (bu/ac)

Type of Crop	67% or less cropped	Greater than 67% but less than 90% cropped	90% or more cropped
Wheat on stubble	36.6	35	44.5
Wheat on fallow	45.9	48.5	–
Barley on stubble	65	49.2	75.8
Barley on fallow	82.5	–	–
Rapeseed on stubble	–	–	26
Rapeseed on fallow	–	40	30

- not applicable

TABLE 5.13

Group Average Crop Yields (1977-81) (bu/ac)

Type of Crop	67% or less cropped	Greater than 67% but less than 90% cropped	90% or more cropped
Wheat on stubble	32.5	33.6	37.1
Wheat on fallow	42.8	49.3	41.7
Barley on stubble	52	51.6	60.7
Barley on fallow	69.8	68.7	-
Rapeseed on stubble	-	-	25.9
Rapeseed on fallow	-	32.9	-

- not applicable

reported that their stubble crop yields averaged about 89% of fallow yields for wheat. Farmers in Group 1 however reported that stubble crop yields averaged about 76% of fallow yields for wheat and about 74% for barley. In comparison Group 2 farmers had averaged about 68% for wheat and about 75% for barley. An inter-group comparison reveals that wheat, barley and rapeseed yields on stubble obtained by continuous croppers have averaged about 80%, 87% and 78% respectively of fallow yields obtained by non-continuous croppers. Although stubble yields for the continuous croppers expressed as a percentage of fallow yields obtained by non-continuous croppers seem exceptionally high, they indicate trends similar to the results of the analysis of AHCIC yield data. An inter-group comparison of stubble yields for the three groups indicates that continuous croppers reported obtaining about 12% higher yields for wheat and 17% higher yields for barley than the other two groups.

Stubble and Fallow Management Prior to Seeding

Continuous croppers seem to manage their stubble prior to seeding with considerable difference. Similarly, non-continuous croppers seem to manage their fallow differently. In fact, there was so much variation between the farmers in all three groups, that it was not possible to arrive at typical practices for each group. An example of stubble and fallow management for one non-continuous cropper

is presented in Table 5.14. Similarly, Table 5.15 shows an example of how one continuous cropper manages his stubble. In all cases, soil conditions and amount of trash cover seemed to dictate the kind of tillage operation performed on stubble prior to seeding.

Seeding and Fertilizing

Table 5.16 shows the frequency of use of different seeding implements, for the three groups. The Hoe Drill and Discer appear to be the most commonly used seeding equipment with continuous croppers prefering the Hoe Drill over all other methods of seeding. Again, the type of seeding equipment used is dictated by soil conditions at the time of planting. In recent years, banding fertilizer has gained popularity among all groups. The survey indicated that 15 out of 22 respondents (66%) had banded fertilizer in the fall and the remaining 7 respondents were considering this technique of adding fertilizer for the following year. All respondents indicated seeing real gains in yields by using this technique as opposed to the more traditional ways of broadcasting fertilizer.

Machinery Availability and Use, 1981

A complete list of all machinery and buildings was requested from each respondent to determine differences in machinery capacity and investment, between the three groups. Although there was a great deal of intra-group variations,

TABLE 5.14

Stubble and Fallow Management by Non-Continuous Cropper

Land Preparation and seeding of stubble in 1981

Fall ops after 1980		Spring Operations Prior to Seeding				Seeding	Post seed tillage spraying operations				Harvest Operations	
1st op	2nd op	1st op	2nd op	3rd op	4th op		1st op	2nd op	3rd op	4th op	1st op	2nd op
Banding	Spreading – Avadex	–	–	–	–	Discer	Harrow and Rodweed	Spraying –	–	–	Swath	Combine

Land Preparation and seeding of fallow in 1981

Fall fertilizing / herbicide Application		Spring Operations Prior to Seeding				Seeding	Post seed tillage spraying operations				Harvest Operations	
1st op	2nd op	1st op	2nd op	3rd op	4th op		1st op	2nd op	3rd op	4th op	1st op	2nd op
Banding	Spreading – Avadex	–	–	–	–	Discer	Harrow and Rodweed	Spraying –	–	–	Swath	Combine

TABLE 5.14

Continued

Preparation of Summerfallow in 1981

			Spring, summer and fall operations			
1st op	2nd op	3rd op	4th op	5th op	6th op	7th op
Cultivate and Harrow	Cultivate and Harrow	Rodweed	Rodweed	–	–	–

TABLE 5.15

Stubble Management by Continuous Cropper

Land Preparation and seeding of stubble in 1981

Fall ops after 1981		Spring Operations Prior to Seeding				Seeding	Post seed tillage / spraying operations				Harvest Operations	
1st op	2nd op	1st op	2nd op	3rd op	4th op		1st op	2nd op	3rd op	4th op	1st op	2nd op
Banding	–	Cultivate and harrow	Disc and Harrow	–	–	Hoe Drill	Spraying	Spraying	–	–	Swath	Combine

TABLE 5.16

Seeding Method and Banding Fertilizer-Frequency of Use

Item	67% or less cropped	Greater than 67% but less than 90% cropped	90% or more cropped
Number of farms	7	8	7
Hoe Drill	3	5	7
Press Drill	0	0	0
Air Seeder	0	2	1
Discer	4	1	5
Banding	5	5	5

some broad trends were noticeable. It was noted that continuous croppers tended to have newer machinery than non-continuous croppers and were also more inclined to custom hire for certain field operations. For example, spraying of herbicides was usually done by custom operators. In terms of machinery capacity, continuous croppers generally had bigger machinery than non-continuous croppers. For example, the standard field tractor for a non-continuous cropper fell in the 130-150 H.P. range while for the continuous cropper it fell in the 220-300 H.P. range. The standard combine for the non-continuous cropper was a 50" P.T.O. combine while the continuous cropper, on the average, had a 55" self propelled combine.

The larger acreages cultivated by the continuous croppers could account for the difference in machinery capacity. On the average, continuous croppers had about twice as much money invested in machinery as compared to the non-continuous croppers, although on a per cultivated acre basis, there does not seem to be any difference. However, this finding will be put to the test more vigorously, in the case farm simulation.

Table 5.17 shows an example of a complete machinery and building inventory list for a continuous cropper while Table 5.18 gives an example of machinery owned by a non-continuous cropper. These were selected out of the sample for illustrative purposes.

TABLE 5.17

Machinery Availability and Use in 1981 for Non-Continuous
Cropper

Item	Size	Year of Purchase	Purchase Price ($)
A. Tillage and Planting Machinery			
Cultivator	26 ft.	1971	3,000
Rodweeder	26 ft.	1972	600
Rodweeder	36 ft.	1972	4,100
Harrow	50 ft.	1979	4,900
Discer	42 ft.	1978	11,000
Grain Dryer	500 bu. batch	1967	4,000
Sprayer	60 ft.	1977	600
Herbicide Applicator	28 ft.	1976	600
B. Harvest Machinery			
P.T.O. Swather	21 ft.	1973	2,100
S.P. Swather	18 ft.	1975	300
P.T.O. Combine	50 in.	1981	42,000
Truck	3 Ton	1972	7,000
Truck	1/2 Ton	1979	14,000
Auger	34 ft. x 8 in.	1980	1,100
Auger	26 ft. x 6 in.	1966	800
C. Tractors			
1.	145 H.P.	1979	39,000
2.	120 H.P.	1980	20,000
3.	40 H.P.	1967	3,000
D. Buildings			
Grain Storage	55,000 bu.	–	–
Machine Storage			
1.	40 ft.x80 ft.	1955	10,000
2.	40 ft.x48 ft.	1981	30,000

TABLE 5.18

Machinery Availability and Use in 1981 for Continuous Cropper

Item	Size	Year of Purchase	Purchase Price ($)
A. Tillage and Planting Machinery			
Cultivator	41 ft.	1981	13,500
Cultivator	28 ft.	1978	7,500
Double Disc.	↓ 24 ft.	1977	8,000
Harrow	50 ft.	1977	3,700
Hoe Drill	28 ft.	1974	12,500
Grain Dryer	300 bu. batch	1976	12,000
Sprayer	60 ft.	1978	3,800
Herbicide Applicator	28 ft.	1978	3,000
Fertilizer Applicator	40 ft.	1975	3,000
B. Harvest Machinery			
P.T.O. Swather	20 ft.	1966	1,600
S.P. Swather	20 ft.	1978	12,000
S.P. Combine	55 in.	1979	76,000
Truck	3 Tons	1974	9,000
Truck	4 Tons	1979	20,000
Truck	3/4 Ton	1963	1,600
Truck	3/4 Ton	1970	1,800
Truck	1/2 Ton	1981	10,700
Trailer	10 Ton	1979	2,500
Auger	50 ft. x 10 in.	1981	3,900
Auger	50 ft. x 10 in.	1966	900
Auger	35 ft. x 8 in.	1981	1,600
Auger	26 ft. x 8 in.	1981	1,200
C. Tractors			
1.	230 HP	1981	65,000
2.	130 HP	1978	25,000
3.	130 HP	1981	26,000
4.	35 HP	1955	500
D. Buildings			
Grain Storage	90,000 bu.		
Machinery Storage	32 ft. x 40 ft.	1976	10,000

D. A Survey of Attitudes and Beliefs

Eighteen statements dealing with the benefits and disadvantages of both summerfallowing and continuous cropping were put forth to the 22 farmers in the sample. Farmers were asked to rate their responses on a scale of 1 to 5 where 1 implied that they strongly disagreed with the statement and 5 implied that they strongly agreed with the statement. As described in Chapter 4 the 22 farmers were divided into three groups. Farmers in group 1 had 67% or less of their cultivated land under crop. Farmers in group 2 had between 67% and 90% of their cultivated land under crop and farmers in group 3 had 90% or greater cropping intensity. The results for each group are shown in Appendix III and illustrated in Figure 5.1 and Figure 5.2.

Perceived Value of Summerfallow

Moisture Conservation

Fifty seven percent of respondents in Group 1 and 37% of respondents in Group 2 agreed or strongly agreed that summerfallowing was the best way to conserve soil moisture. All the continuous croppers disagreed or strongly disagreed with this statement.

Weeds and Pest Control

Forty-two percent of those in Group 1 and 37% of those in Group 2 agreed or strongly agreed that summerfallowing was the best method of controlling weeds

Figure 5.1

MEAN RESPONSES TO OPINION RELATED STATEMENTS

Legend
< 67% Cropped
67 % to 86% Cropped
86% + > Cropped
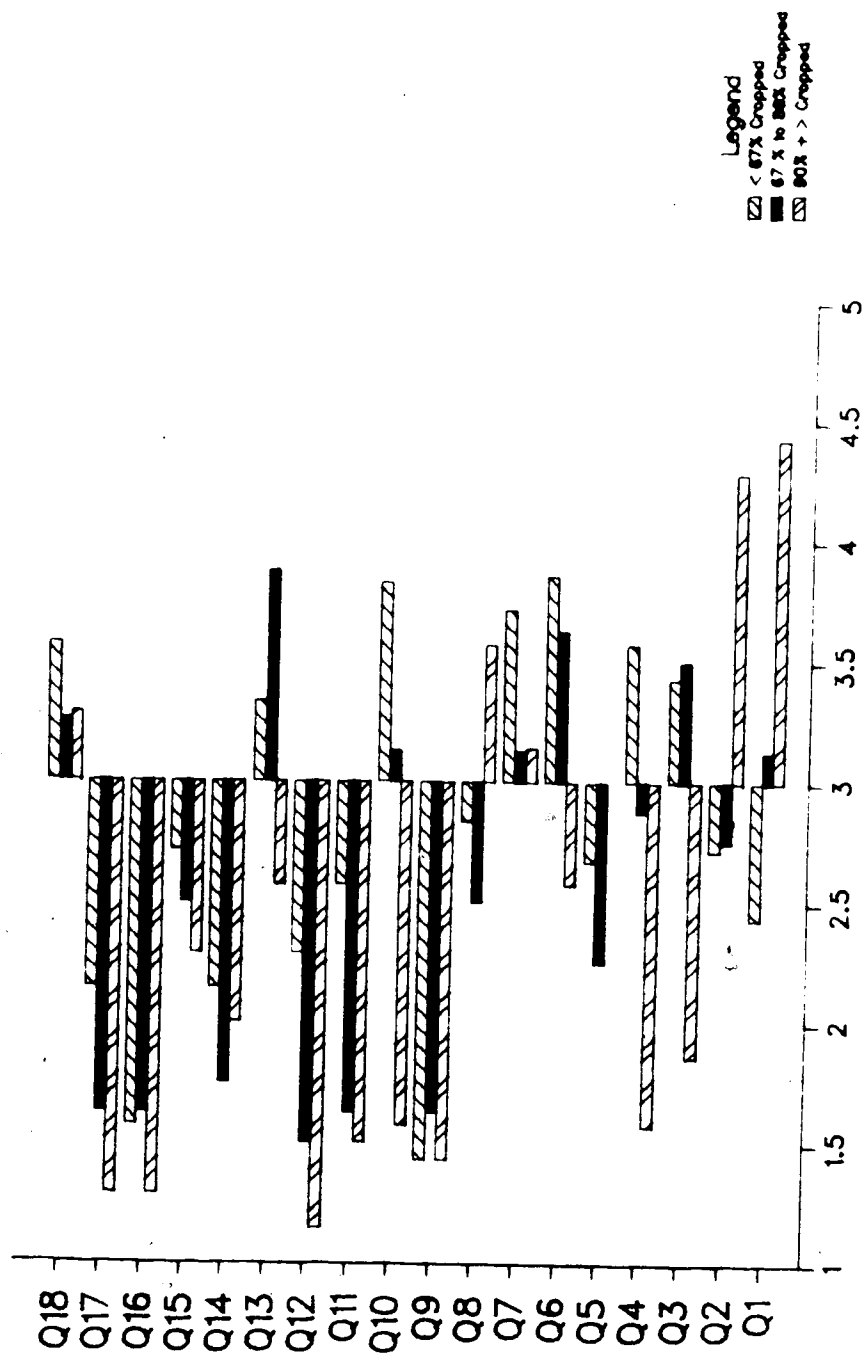
Figure 5.2

MEAN RESPONSES TO CHANGES IN PHYSICAL AND ECONOMIC VARIABLES
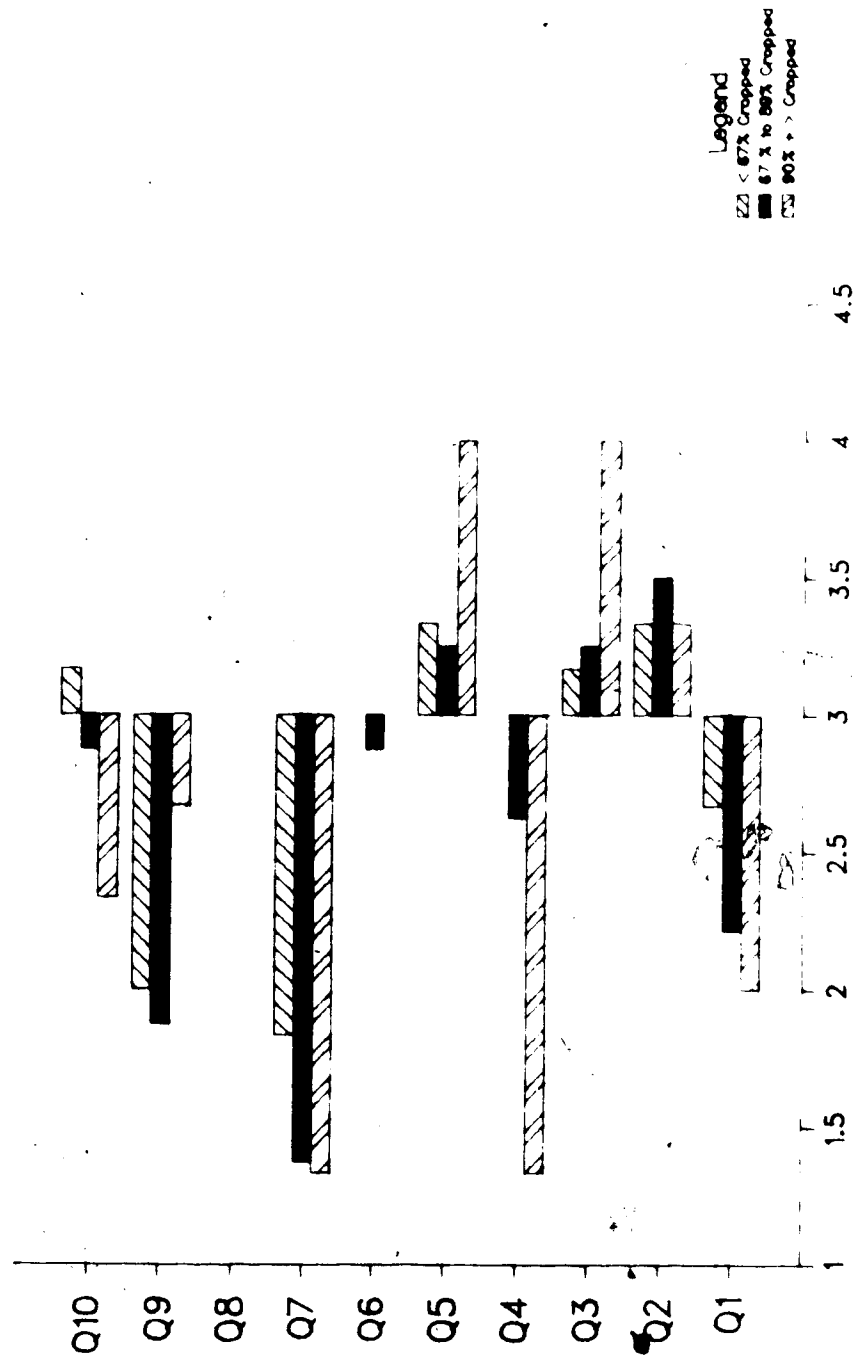
and crop pests. All the continuous croppers surveyed disagreed or strongly disagreed with this statement.

Tradition

Five out of 7 respondents in Group 1 (71%) and 5 out of 8 respondents in Group 2 (62%) disagreed or disagreed strongly that tradition was an important reason in continuing to summerfallow. However, 4 of the 7 continuous croppers (57%) agreed or strongly agreed that this was so.

Operating Costs

Four of the 7 respondents in Group 1 (57%) agreed or strongly agreed that by summerfallowing, a farmer reduces his operating costs. Two of the 7 did not have any strong opinions on this statement. Five of the 8 respondents in Group 2 did not have any strong opinions about this statement either, and only 1 of the 8 agreed with it. Two of the 7 continuous croppers agreed with this statement while 3 of them did not have any strong opinions.

Income Stability

Forty two percent of those in group 1 and 57% of those in Group 2 agreed or strongly agreed that by summerfallowing a producer achieves greater income stability. Only 2 of the 7 continuous croppers (28%) thought that this was so.

Concerns about Summerfallow

Increased Soil Salinity

Four of the 7 Group 1 respondents (57%) and 7 of the 8 Group 2 respondents (87%) agreed or strongly agreed that summerfallowing is bad because it increases soil salinity. Six of the 7 continuous croppers (85%) strongly agreed with this statement.

Soil Erosion and Nitrogen Leaching

Four of the 7 Group 1 respondents (57%), and all of the Group 2 and Group 3 respondents agreed that summerfallowing should be discouraged because it contributes to severe wind and water erosion coupled with nitrogen leaching.

Concerns about Continuous Cropping

Soil Moisture

Three of the 7 respondents in Group 1 (42%) and 3 of the 8 respondents in Group 2 (37%) disagreed or strongly disagreed with the statement that soil moisture is not such a critical problem in continuous cropping as is the general belief. Six of the 15 respondents in Groups 1 and 2 had no strong opinion on this statement. Four of the 7 continuous croppers however, strongly agreed with this statement.

Returns To Investment

All of the continuous croppers interviewed agreed
or strongly agreed that on a long term average,
continuous cropping gives higher returns per acre
compared to other cropping programs that included more
fallow. Only 28% of those in Group 2 and 1 of the 7
respondents in Group 1 (14%) agreed that this was so.

Capital Investment On Machinery

Three of the 7 respondents in Group 1 (42%) and 5
of the 8 respondents in Group 2 (62%) felt that
producers who continuously crop their land require more
capital investment on machinery. Two of the 7 continuous
croppers strongly agreed with this statement, while 2
others strongly disagreed. Three of the 7 had no strong
opinions.

Use of Land Base

All of the non-continuous croppers and 85% of the
continuous croppers agreed or strongly agreed that
continuous cropping makes better use of the land base.

Stubble Yields

More than 85% of the continuous croppers agreed or
strongly agreed that stubble yields were high enough to
outweigh increased herbicide and other costs, resulting
in higher net farm incomes as compared to
summerfallowing. However, only 14% of those in Group 1
and 25% of those in Group 2 felt that this was so.

Seeding Equipment

Four of the 7 continuous croppers (57%) agreed or strongly agreed that at the present time, seeding equipment for seeding on stubble was inadequate and could be vastly improved. However, 6 of the 8 respondents in Group 2 (75%) and 3 of the 7 respondents in Group 1 (42%) disagreed or strongly disagreed with this statement.

Increased Attention to Detail

Seventy one percent of Group 1 farmers and 87% of the Group 2 farmers seemed to feel that continuous cropping does require increased attention to detail eg. timing of herbicide application, and 85% of the continuous croppers agreed that this was so.

Labour and Machinery

There were conflicting opinions among the non-continuous croppers about whether summerfallowing allows a producer to better plan use of his labour and machinery. Four of the 7 respondents in Group 1 did not agree that this was the case while 5 of the 8 respondents in Group 2 agreed or strongly agreed. Similarly, the continuous croppers were also divided in their opinions. Three of them strongly disagreed while 2 strongly agreed and the remaining 2 had no strong opinion.

Feasibility of Continuous Cropping

All sample farmers, regardless of grouping agreed that improvements in blended fertilizers and the practice of banding fertilizer have made continuous cropping more economically feasible today than 10 years ago. Fully 50% of all respondents also felt that new snow management techniques have increased this feasibility. More than 90% of all respondents felt that technological improvements in the area of herbicides are encouraging farmers towards continuous cropping.

Adjustments in Summerfallow Acreage

Sample farmers were asked to indicate the extent to which their summerfallow acreage would change in response to changes in various physical, economic and policy variables. The results are presented in Appendix III.

Two of the 7 respondents in Group 1 and 6 of the 8 respondents in Group 2 indicated that they would reduce summerfallow acreage if there was adequate spring moisture. Reductions in acreage would range between 10 and 20 percent in all cases except 1 where the reduction would be greater than 20%. In a dry spring 2 of the 7 respondents in Group 1 and 5 of the respondents in Group 2 would increase summerfallow acreage by between 10 and 20%. Only 1 of the 7 continuous croppers indicated he would do the same.

If herbicides increase in price by 50%, the majority of producers in all groups would not adjust their summerfallow

acreage. Similarly, an increase in price of fertilizers by 50% would not affect the summerfallow acreage of the majority of producers in all groups. Two of the respondents in Group 2 and 3 of the 8 respondents in Group 3 would reduce summerfallow acreage in response to a 50% increase in fuel prices.

Only 1 of the 22 respondents would reduce summerfallow acreage by between 10 and 20% in response to a 50% increase in land prices. A 50% increase in grain and oilseed price would cause 16 of the 22 respondents to decrease summerfallow acreage. None of the respondents in all three groups would make any adjustment to summerfallow acreage in response to a 50% increase in interest rates. Similarly, the majority of respondents indicated they would not make any adjustment to summerfallow acreage in response to a 50% increase in farm machinery prices.

If no grain quotas existed, 9 of the 15 respondents in Groups 1 and 2 would decrease summerfallow acreage. 3 of the 9 respondents would decrease summerfallow acreage by between 10 and 20% and the remaining 6 by greater than 20%.

E. Summary Observations

Although no statistical testing of the responses was done, it is possible to make summary observations about them. The survey suggests that in the study area, moisture conservation, weed control and income stability stand out as the most important reasons for including summerfallow in the

cropping program. All of the continuous croppers feel that
summerfallowing should be discouraged due to its negative
effects and surprisingly, the majority of those respondents
in the non-continuous cropping category also feel the same
way. The survey also reveals that there is a trend towards
less summerfallow in the study area. However, the majority
of the non-continuous croppers are not yet convinced that
stubble yields are sufficiently high or reliable to make
continuous cropping a better paying proposition.
Furthermore, the perception that continuous cropping
requires greater investment in machinery, requires greater
attention to detail and is still plagued with physical
problems such as seeding on stubble with inadequate
machinery are all reasons that deter non-continuous croppers
from practicing more intensive cropping.

The survey also suggests that a good number of farmers
seem to be making decisions on a short term or year to year
basis with substantial adjustments to summerfallow acreage
based on spring soil moisture conditions and marketability
of crops. The majority of producers would react to increased
grain and oilseed prices and the absence of grain quota
restrictions by reducing their summerfallow acreage
substantially.

Input-price increases however, do not seem to impact on
summerfallow acreage to any significant degree. Low grain
prices and uncertainty of markets for their crops were
repeatedly mentioned by non-continuous croppers as two

important reasons detering them from more intensive cropping. On the other hand, there was general consensus among this group that technological improvements in herbicides, fertilizers and moisture conservation techniques have in recent years, increased the economic feasibility of continuous cropping.

F. Case Farm Simulation

In a step by step procedure, the economic consequences at the farm level, of changing cropping programs and the key economic variables associated with them were investigated by simulating the case farm over the ten year period 1982 to 1991.

In the first experiment, (base situation), output prices were held constant at the mean while yields were allowed to be stochastic. The ten year mean prices (1972-81) for spring wheat, barley and rapeseed were $3.84/bu, $2.17/bu and $4.96/bu respectively. The mean expected ending equities and variances for each of the 12 strategies investigated were determined and are shown in Table 5.19. The 12 strategies were then represented in Expected Income - Variance (E-V) space as shown in Fig. 5.3.

By stochastic dominance concepts described in Chapter 2, the dominant strategies are S_3, S_5, S_6 and S_9. S_9 has a higher expected equity and lower variance than S_7 S_8 and S_{12}. Similarly, S_3, S_5 and S_6 clearly dominate all other strategies lying to their north-west. S_3 represents a

TABLE 5.19

Expected Ending Equities and Standard Deviations
Prices Constant at the Mean and Yields Stochastic

Strategy	Mean Equity ($)	C.V. (%)	Standard Deviation ($)
S 1	1,483,252	0.4	6,358
S 2	1,458,269	0.5	6,787
S 3	1,498,438	0.4	6,289
S 4	1,491,258	0.4	6,613
S 5	1,452,182	0.4	6,042
S 6	1,500,674	0.4	6,575
S 7	1,478,446	0.7	10,802
S 8	1,447,612	0.7	9,919
S 9	1,513,492	0.6	9,690
S 10	1,418,079	0.5	6,761
S 11	1,400,084	0.5	7,082
S 12	1,351,039	0.9	12,900

Figure 5.3
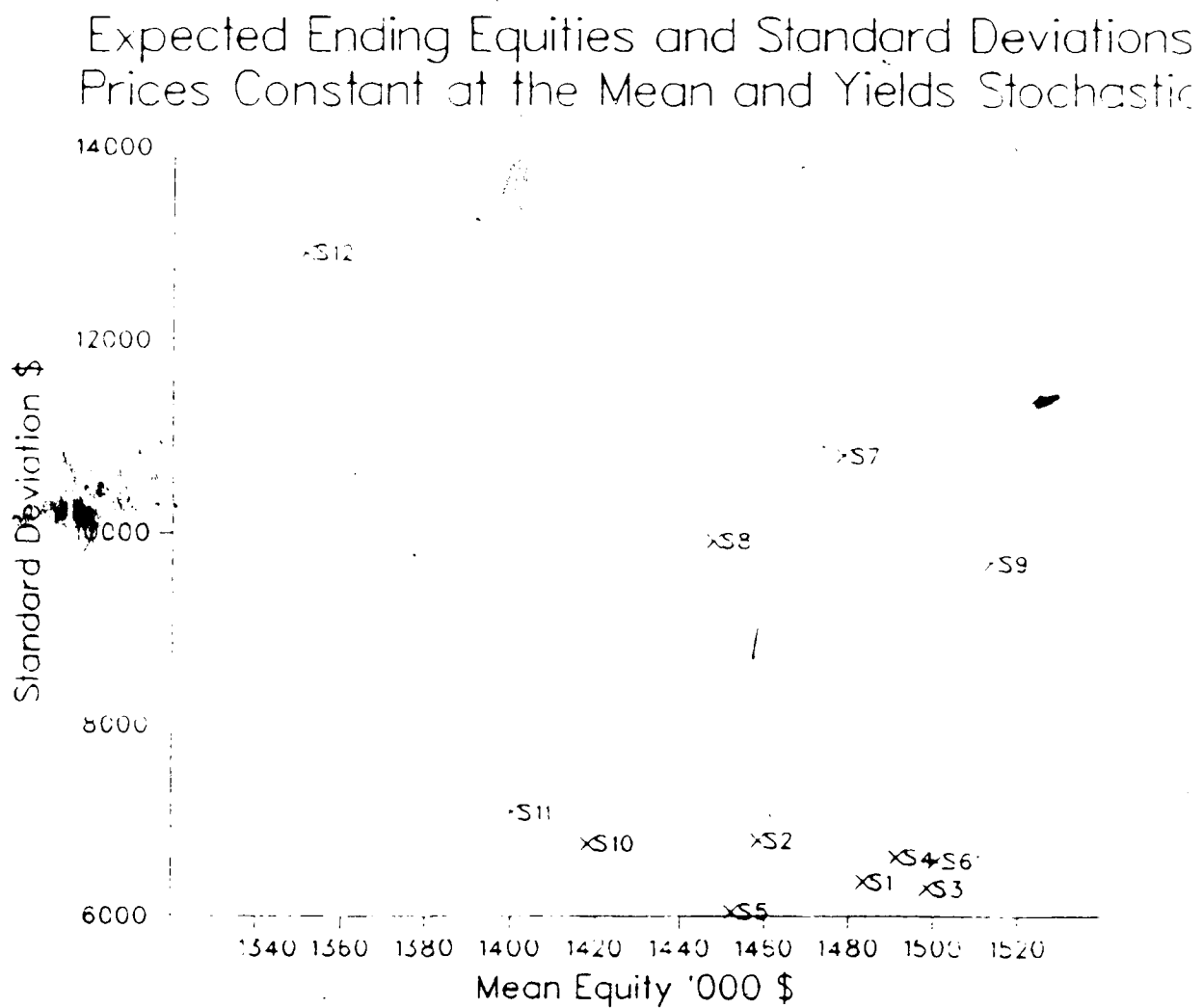
Expected Ending Equities and Standard Deviations
Prices Constant at the Mean and Yields Stochastic

1/2-1/2 cropping program with no custom hire and machinery selling policy at 13% remaining useful life. S_5 represents a 1/3-2/3 cropping program with no custom hire and machinery selling policy at 67% remaining useful life. S_6 depicts a 1/3-2/3 cropping program with no custom hire and machinery selling policy at 13% remaining useful life, while S_9 represents a continuous cropping operation with no custom hire and machinery selling policy set at 13% remaining useful life.

If the farmer moves from a 1/2-1/2 cropping program (S_3) to a 1/3-2/3 (S_6) cropping program, his expected equity increases by $2,236 (less than 0.2%), over the ten year period while the risk, as measured by the standard deviation of the mean expected equity, increases by $286 (4.5%). Moving from a 1/2-1/2 cropping program to a continuous cropping operation (S_9) increases his expected equity by $15,053 (1%), while the risk associated with this move increases by $3,401 (54%). These results are shown in Table 5.20.

When output prices and yields are both stochastic, for the ten year period, the dominant strategies are S_3, S_6 and S_9. These results are illustrated in Table 5.21 and shown graphically in Fig. 5.4. Moving from a 1/2-1/2 cropping program to a 1/3-2/3 cropping program results in an increase in expected equity of $9,289 (0.6%), while risk increases by $4,601 (25.6%). Similarly, moving from a 1/2-1/2 cropping program to a continuous cropping operation results in an

TABLE 5.20

A Comparison of Dominant Strategies
Prices Constant, Yields Stochastic

Strategy	Increase in Expected Equity	Increase in Risk (%)
S3 - S6	$2236 (0.2%)	4.5
S6 - S9	$12,818 (0.8%)	32
S3 - S9	$15,053 (1%)	54

TABLE 5.21

Expected Ending Equities and Standard Deviations Prices and
Yields Stochastic

Strategy	Mean Equity ($)	C.V. (%)	Standard Deviation ($)
S 1	1,478,111	1.2	17,958
S 2	1,453,297	1.2	18,010
S 3	1,493,344	1.2	17,958
S 4	1,493,132	1.5	22,518
S 5	1,454,103	1.5	22,476
S 6	1,502,633	1.5	22,559
S 7	1,485,218	2.0	30,285
S 8	1,453,802	2.0	29,600
S 9	1,520,168	2.0	29,694
S 10	1,410,714	1.3	18,671
S 11	1,399,900	1.6	22,184
S 12	1,355,285	2.3	31,194

Figure 5.4

Expected Ending Equities and Standard Deviations Prices Yields Stochastic
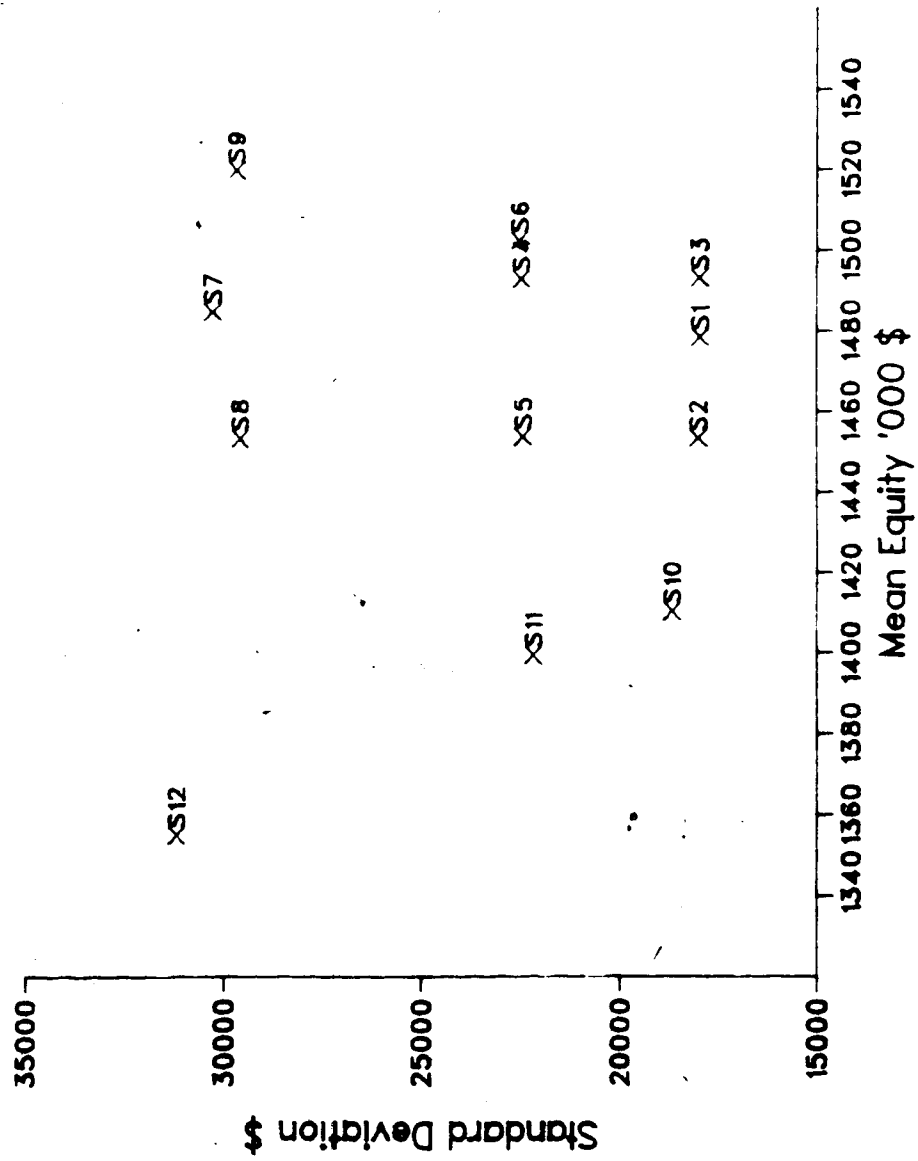
increase in expected equity of $26,824 (1.79%), with an increase in risk of $11,236 (65%).(Table 5.22) These results are consistent with what was expected, where continuous cropping is associated with higher payoff and higher risk. However, the difference in expected equities between the three different strategies appears to be small relative to the greater increase in risk that needs to be assumed, in a continuous cropping operation.

A comparison of expected equities for the dominant strategies for the two situations when prices are held constant and prices are stochastic, indicates that there are very small differences in equity. However, keeping prices constant causes a substantial reduction in variance, as compared to the situation when prices are stochastic. This suggests that uncertainty of prices is a more important factor than yield uncertainty contributing to the overall problem of unstable incomes.

The standard deviation of mean expected equities provides an indication of the amount of income variability associated with each cropping program. As expected, the standard deviations of mean expected equities decreased as the proportion of summerfallw in the rotation increased.

An evaluation of the three different strategies, S_3, S_8 and S_9 based on confidence intervals, is possible by invoking the Central Limit Theorem that proves that all probability distributions converge to a normal distribution. Probability statements about attaining specified levels of

TABLE 5.22

A Comparison of Dominant Strategies
Prices and Yields Stochastic

Strategy	Increase in Expected Equity	Increase in Risk (%)
S3 - S6	$9289 (0.6%)	25.6
S6 - S9	$17,535 (1.2%)	31.6
S3 - S9	$26,824 (1.79%)	65

actual equity for a given level of expected equity are calculated and shown in Table 5.23. The same results are portrayed graphically in Fig. 5.5 These values have been calculated for the situation when prices and yields are both stochastic. Thus, as an example, for a 1/2-1/2 cropping program, with a mean expected equity of $1,493,344, there is a 20% chance that the actual equity will be $1,478,259, a difference of $15,085. Similarly, for a continuous cropping program with a mean expected equity of $1,520,168, there is a 20% chance that the actual equity obtained will be $1,495,225, a difference of $24,943.

Farm Income Statement and Balance Sheet

The dryland crop simulation model provides an annual breakdown of crop revenues and expenses, with a partial financial statement for the particular year. Since the presentation of financial statements by the model is cumbersome, net farm income statements and balance sheets, for the three dominant strategies were derived from the volumes of information generated by the computer. They are presented in Tables 5.24 through to Tables 5.29. These financial summaries were derived for the situation when prices and yields are both stochastic in the simulation.

The farm income statements show the relative profitability of each type of cropping program and the relative stability of incomes for the ten year simulation period. The year to year fluctuations in incomes for all

Figure 5.5

Evaluation of Strategies Based on Confidence Intervals
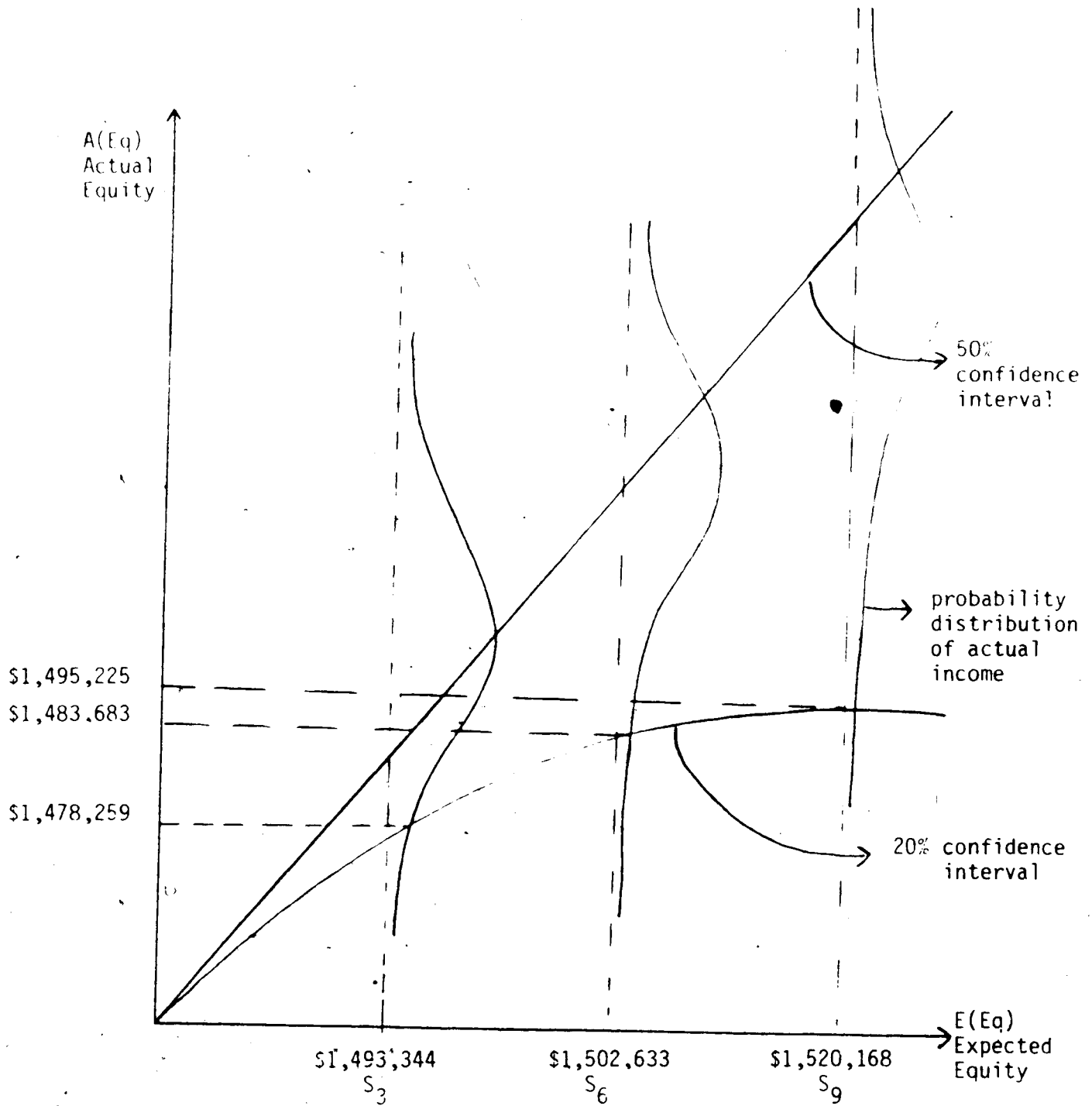
TABLE 5.23

Probability Statements About Attaining Specified Levels of Actual Equity for a Given Level of Expected Equity With Prices and Yields Stochastic

Strategy	Expected Equity ($)	Probability Levels						
		1%	5%	10%	20%	30%	40%	50%
S3	1,493,344	1,451,501	1,463,713	1,470,357	1,478,259	1,484,005	1,488,854	1,493,344
S6	1,502,633	1,450,070	1,465,410	1,473,757	1,483,683	1,490,902	1,496,993	1,502,633
S9	1,520,168	1,450,980	1,471,172	1,482,159	1,495,225	1,504,727	1,512,744	1,520,168

TABLE 5.24

Farm Income Statement for 1/2 - 1/2 Cropping Program (S3)(Year 1 to Year 10)

	1	2	3	4	5	6	7	8	9	10
REVENUE										
Crop Revenue	226964	104156	93593	108864	92443	87931	113536	122947	124206	118613
Final Grain Payment	0	0	0	0	0	0	0	0	0	0
Crop Insurance Payment	0	0	0	0	0	0	0	0	0	0
WGSA Payment	0	0	0	0	0	0	0	0	0	0
Total Revenue	226964	104156	93593	108864	92443	87931	113536	122947	124206	118613
Change in Crop Inventory	-42726	37035	8627	-16774	-11248	3681	16559	18464	-150	-3620
Gross Income	**184238**	**141191**	**102220**	**92090**	**81195**	**91612**	**130095**	**141411**	**124056**	**114993**
EXPENSES										
Seed	5221	5093	5515	5152	5082	5100	5487	5128	5082	5082
Chemicals	8320	8295	8370	8301	8295	8295	8362	8295	8295	8295
Fertilizer	8002	8002	8002	8002	8002	8002	8002	8002	8002	8002
Fuel and Oil	5306	5242	5477	5249	5301	5413	5422	5253	5351	5436
Machine Repair	3674	4019	4653	4715	5094	4915	5298	5341	5803	6339
Building Repair	1789	1789	1789	1789	1789	1789	1789	1789	1789	1789
Crop Insurance Premium	2017	2040	1913	1995	2058	2030	1913	1988	2058	2058
WGSA Contributions	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Other Supplier/Services	11160	8644	9002	8940	8628	17563	9251	8776	9121	8185
Wages and Salaries	10400	10400	10521	10400	10400	10479	10476	10400	10428	10400
Interest Payment	5659	5258	4792	4248	3614	2874	3538	2526	1333	1246
Depreciation	18395	17048	15835	14743	13759	6695	12784	11982	11260	11075
Total Expenses	**81443**	**77330**	**77369**	**75034**	**73522**	**73044**	**73822**	**70980**	**70022**	**69407**
Net Farm Income	102795	63861	24851	17056	7673	18568	56273	70431	54304	45586
Other Income[1]	15445	23270	29856	36454	43699	50743	60316	71965	85327	100697
Total Net Income	**118240**	**87131**	**54707**	**53510**	**51372**	**69311**	**116589**	**142396**	**139631**	**146283**

[1]primarily from interest earned on cash balances

TABLE 5.25

Balance Sheet at End of Year for 1/2 - 1/2 Cropping Program (S3) (Year 1 to Year 10)

	1	2	3	4	5	6	7	8	9	10
ASSETS										
Cash on Hand	177147	166998	210827	257469	299302	346421	418897	501022	594832	691771
Crop inventory	33313	70348	78975	62202	50953	54634	71193	89657	88507	85887
Total Current Assets	**210460**	**237346**	**289802**	**319671**	**350255**	**401055**	**490090**	**590679**	**683339**	**777658**
Land	640000	640000	640000	640000	640000	640000	640000	640000	640000	640000
Buildings	40249	35776	31304	26832	22360	17888	13416	8944	4472	0
Machinery	134704	122129	110766	100495	91208	88985	80673	73163	66375	59772
Total Fixed Assets	**814953**	**797905**	**782070**	**767327**	**753568**	**746873**	**734089**	**721107**	**710847**	**699772**
Other Assets¹	50000	50000	50000	50000	50000	50000	50000	50000	50000	50000
Total Assets	1075413	1085251	1121872	1136998	1153823	1197928	1274179	1361786	1444186	1527430
LIABILITIES										
Tax Payable	29382	0	9644	7419	7539	11369	18711	23420	26489	28053
Term Liabilities	32891	29440	25522	21061	15965	19656	14036	7404	6921	6351
Total Liabilities	**62273**	**29440**	**35166**	**28480**	**23504**	**31025**	**32747**	**30824**	**33410**	**34404**
Beginning Equity	933447	1013140	1055811	1086706	1108518	1130319	1166903	1241432	1330962	1410776
+ Total Net Income	118240	87131	54707	53510	51372	69311	116589	142396	139631	146283
- Living Expenses	23855	15075	18986	18339	18375	19490	21339	22480	23185	23545
- Income Tax	14692	29385	4826	13359	11196	13237	20690	30386	36632	40488
Ending Equity	1013140	1055811	1086706	1108518	1130319	1166903	1241432	1330962	1410776	1493026
Total Liab + End Equity	**1075413**	**1085251**	**1121872**	**1136998**	**1153823**	**1197928**	**1274179**	**1361786**	**1444186**	**1527430**
Growth in Equity (% p.a.)	8.54	4.21	2.93	2.01	1.97	3.24	6.39	7.21	6.00	5.83

¹includes parts and supplies, other buildings, improvements and equipment

143

TABLE 5.26

Farm Income Statement for 1/3 - 2/3 Cropping Program (S6) (Year 1 to Year 10)

	1	2	3	4	5	6	7	8	9	10
REVENUE										
Crop Revenue	227355	120878	111166	122777	107706	101499	120874	135062	146797	124655
Final Grain Payment	0	0	0	0	0	0	0	0	0	0
Crop Insurance Payment	0	0	0	0	0	0	0	0	0	0
WGSA Payment	0	0	0	0	0	0	0	0	0	0
Total Revenue	227355	120878	111166	122777	107706	101499	120874	135062	146797	124655
Change in Crop Inventory	-36529	46400	7187	-13506	-9851	2149	18883	29847	-14403	5197
Gross Income	**190826**	**167278**	**118353**	**109271**	**97855**	**103648**	**139757**	**164909**	**132394**	**129852**
EXPENSES										
Seed	6962	6791	7354	6869	6775	6800	7316	6838	6775	6775
Chemicals	9983	9950	10049	9958	9950	9950	10041	9950	9950	9950
Fertilizer	12552	12552	12552	12552	12552	12552	12552	12552	12552	12552
Fuel and Oil	5953	5929	6037	5944	5936	5955	5982	5838	5465	5447
Machine Repair	4457	4971	5534	5889	6285	6040	6514	6235	5500	5817
Building Repair	1789	1789	1789	1789	1789	1789	1789	1789	1789	1789
Crop Insurance Premium	2239	2280	2112	2237	2294	2271	2117	2236	2294	2294
WGSA Contributions	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Other Supplies/Services	11717	9592	9922	9909	9473	16520	9746	21876	17986	9124
Wages and Salaries	10718	10708	10763	10716	10713	10723	10729	10704	10691	10670
Interest Payment	5659	5258	4792	4248	3614	2874	3538	2526	3965	5326
Depreciation	18395	17048	15835	14743	13759	6695	12784	3030	6011	12242
Total Expenses	**91924**	**88368**	**88239**	**86354**	**84640**	**83669**	**84608**	**85074**	**84478**	**83466**
Net Farm Income	98902	78910	30114	22917	13215	19979	55149	79835	47916	46386
Other Income[1]	14231	22213	29714	36651	43804	50959	60359	72532	86713	102717
Total Net Income	**113133**	**101123**	**59828**	**59568**	**57019**	**70938**	**115508**	**152367**	**134629**	**149103**

[1] primarily from interest earned on cash balances

TABLE 5.27

Balance Sheet at End of Year for 1/3-2/3 Cropping Program (S6) (Year 1 to Year 10)

	1	2	3	4	5	6	7	8	9	10
ASSETS										
Cash on Hand	165345	163120	212257	259535	301626	424422	418322	505907	604463	703593
Crop Inventory	39511	85911	93097	79591	69741	71889	90773	120618	106216	111413
Total Current Assets	**204856**	**249031**	**305354**	**339126**	**371367**	**496311**	**509095**	**626525**	**710679**	**815006**
Land	640000	640000	640000	640000	640000	640000	640000	640000	640000	640000
Buildings	40249	35776	31304	26832	22360	17888	13416	8944	4472	0
Machinery	134704	122128	110765	100494	91207	88984	80672	82114	80575	72805
Total Fixed Assets	**814953**	**797904**	**782069**	**767326**	**753567**	**746872**	**734088**	**731058**	**725047**	**712805**
Other Assets[1]	50000	50000	50000	50000	50000	50000	50000	50000	50000	50000
Total Assets	**1069809**	**1096935**	**1137423**	**1156452**	**1174934**	**1218389**	**1293183**	**1407583**	**1485726**	**1577811**
LIABILITIES										
Tax Payable	27554	762	10941	9531	8688	11452	18003	26575	23067	29324
Term Liability	32891	29440	25522	21061	15965	19656	14036	22024	29589	27917
Total Liabilities	**60445**	**30202**	**36463**	**30592**	**24653**	**31108**	**32039**	**48599**	**52656**	**57241**
Beginning Equity	933447	1009364	1066733	1100960	1125860	1150281	1187281	1261144	1358984	1433070
+ Total Net Income	113133	101123	59828	59568	57019	70938	115508	152367	134629	149103
− Living Expenses	23435	15814	19364	18954	18710	19511	21170	23213	22408	23846
− Income Tax	13781	27940	6237	15714	13888	14427	20475	31314	38135	37757
Ending Equity	1009364	1066733	1100960	1125860	1150281	1187281	1261144	1358984	1433070	1520570
Total Liab + End Equity	**1069809**	**1096935**	**1137423**	**1156452**	**1174934**	**1218389**	**1293183**	**1407583**	**1485726**	**1577811**
Growth in Equity (% p.a)	8.13	5.68	3.21	2.26	2.17	3.22	6.22	7.76	5.45	6.11

[1] includes parts and supplies, other buildings, improvements and equipment

TABLE 5.28

Farm Income Statement for Continuous Cropping Operation (S9) (Year 1 to Year10)

	1	2	3	4	5	6	7	8	9	10
REVENUE										
Crop Revenue	223454	159360	148581	152386	145520	131612	143405	155962	196566	135339
Final Grain Payment	0	0	0	0	0	0	0	0	0	0
Crop Insurance Payment	0	0	0	0	0	0	0	0	0	0
WGSA Payment	0	0	0	0	0	0	0	0	0	0
Total Revenue	223454	159360	148581	152386	145520	131612	143405	155962	196566	135339
Change in Crop Inventory	-23745	61349	-1697	-8438	-26297	-8100	19492	59249	-49593	23938
Gross Income	**199709**	**220709**	**146884**	**143948**	**119223**	**123512**	**162897**	**215211**	**146973**	**159277**
EXPENSES										
Seed	10336	10053	10977	10176	10030	10067	10914	10123	10030	10030
Chemicals	13310	13260	13409	13272	13260	13260	13397	13260	13260	13260
Fertilizer	21652	21652	21652	21652	21652	21652	21652	21652	21652	21652
Fuel and Oil	7446	7408	7490	6967	6947	7214	6813	6872	6722	6758
Machine Repair	6442	7253	8077	7334	7904	8325	7638	8269	8649	9178
Building Repair	1789	1789	1789	1789	1789	1789	1789	1789	1789	1789
Crop Insurance Premium	2533	2542	2444	2491	2564	2529	2438	2478	2564	2564
WGSA Contribution	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Other Supplies/Services	13577	12312	12476	24119	11088	18707	19680	11998	11737	9480
Wages and Salaries	12341	12309	12372	11869	11887	11989	11878	11877	11712	11752
Interest Payment	5659	5258	4792	4248	6246	5394	6781	7137	5651	5218
Depreciation	18395	17048	15835	6221	15497	8014	7230	13249	12381	11602
Total Expenses	**114980**	**112384**	**112813**	**111636**	**110364**	**110440**	**111619**	**110204**	**107647**	**104783**
Net Farm Income	84729	108325	34071	32313	8859	13072	51278	105007	39326	54494
Other Income[1]	10425	19680	28323	36985	45498	55126	65167	76924	91225	109338
Total Net Income	**95154**	**128005**	**62394**	**69295**	**54357**	**68198**	**116445**	**181931**	**130551**	**163832**

[1] primarily from interest earned on cash balances

TABLE 5.29

Balance Sheet at End of Year for Continuous Cropping Operation (S9) (Year 1 to Year 10)

	1	2	3	4	5	6	7	8	9	10
ASSETS										
Cash on Hand	133851	155578	209077	267026	367362	379312	450396	536085	641470	748170
Crop Inventory	52295	113645	111947	103509	77211	69113	88603	147853	98260	122198
Total Current Assets	**186146**	**269223**	**321024**	**370535**	**444573**	**448425**	**538998**	**683939**	**739730**	**870368**
Land	640000	640000	640000	640000	640000	640000	640000	640000	640000	640000
Buildings	40249	35776	31304	26832	22360	17888	13416	8944	4472	0
Machinery	134704	122128	110765	109007	97982	94440	91682	82905	74996	67866
Total Fixed Assets	**814953**	**797904**	**782069**	**775839**	**760342**	**752328**	**745098**	**731849**	**719468**	**707866**
Other Assets[1]	50000	50000	50000	50000	50000	50000	50000	50000	50000	50000
Total Assets	1051099	1117127	1153093	1196374	1204915	1250753	1334096	1465788	1509198	1628234
LIABILITIES										
Tax Payable	21134	4330	11341	12785	8105	11348	17303	36192	17468	37377
Term Liabilities	32891	29440	25522	35681	29963	37670	39653	31392	28987	26151
Total Liabilities	**55025**	**33770**	**36863**	**48466**	**38068**	**49018**	**56956**	**67584**	**46455**	**63528**
Beginning Equity	933447	996074	1083357	1116230	1147908	1166847	1201735	1277140	1398204	1462743
+ Total Net Income	95154	128005	62394	69295	54357	68198	116445	181931	130551	163832
- Living Expenses	21959	17388	19486	19851	18545	19489	20996	25422	21039	25664
- Income Tax	10568	23334	10035	17766	16873	13821	20044	35445	44973	36205
Ending Equity	996074	1083357	1116230	1147908	1166847	1201735	1277140	1398204	1462743	1564706
Total Liab + End Equity	**1051099**	**1117127**	**1153093**	**1196374**	**1204915**	**1250753**	**1334096**	**1465788**	**1509198**	**1628234**
Growth in Equity (% p.a.)	6.71	8.76	3.03	2.84	1.65	2.99	6.27	9.48	4.62	6.97

[1]includes parts and supplies, other buildings, improvements and equipment

three cropping programs is pronounced, although the continuous cropping program shows greater fluctuations in incomes than the other two strategies.

Fig. 5.6 illustrates the paths of total net incomes obtained for the three different dominant strategies over the ten year simulation period. The pronounced year to year fluctuations in total net incomes for all three cropping programs are attributed to actual price and yield fluctuations which occured during the last ten year period.

The model does not permit the reinvestment of cash reserves in the business and hence the reason for the large cash balances. Interest earned at 7% p.a. on cash balances is shown as other receipts in the balance sheet. At the end of the ten year period, the ending equity for the continuous cropping operation is highest and that for the 1/2-1/2 cropping strategy the lowest, although by a relatively marginal amount, considering the greatly reduced yearly variation.

Fertilizer and Herbicide Costs

All input cost coefficients for the 1/2-1/2 cropping program were obtained from the case farmer and were actual costs incurred in 1981. For the 1/3-2/3 and continuous cropping operations, input cost coefficients were estimated from data obtained in the farm survey.

Average fertilizer and herbicide costs per acre for the three strategies S_3, S_6 and S_9 are shown in Table 5.30.

Figure 5.6

Variability of Net Incomes for Dominant Strategies

Legend
S3
S6
S9
△ × □
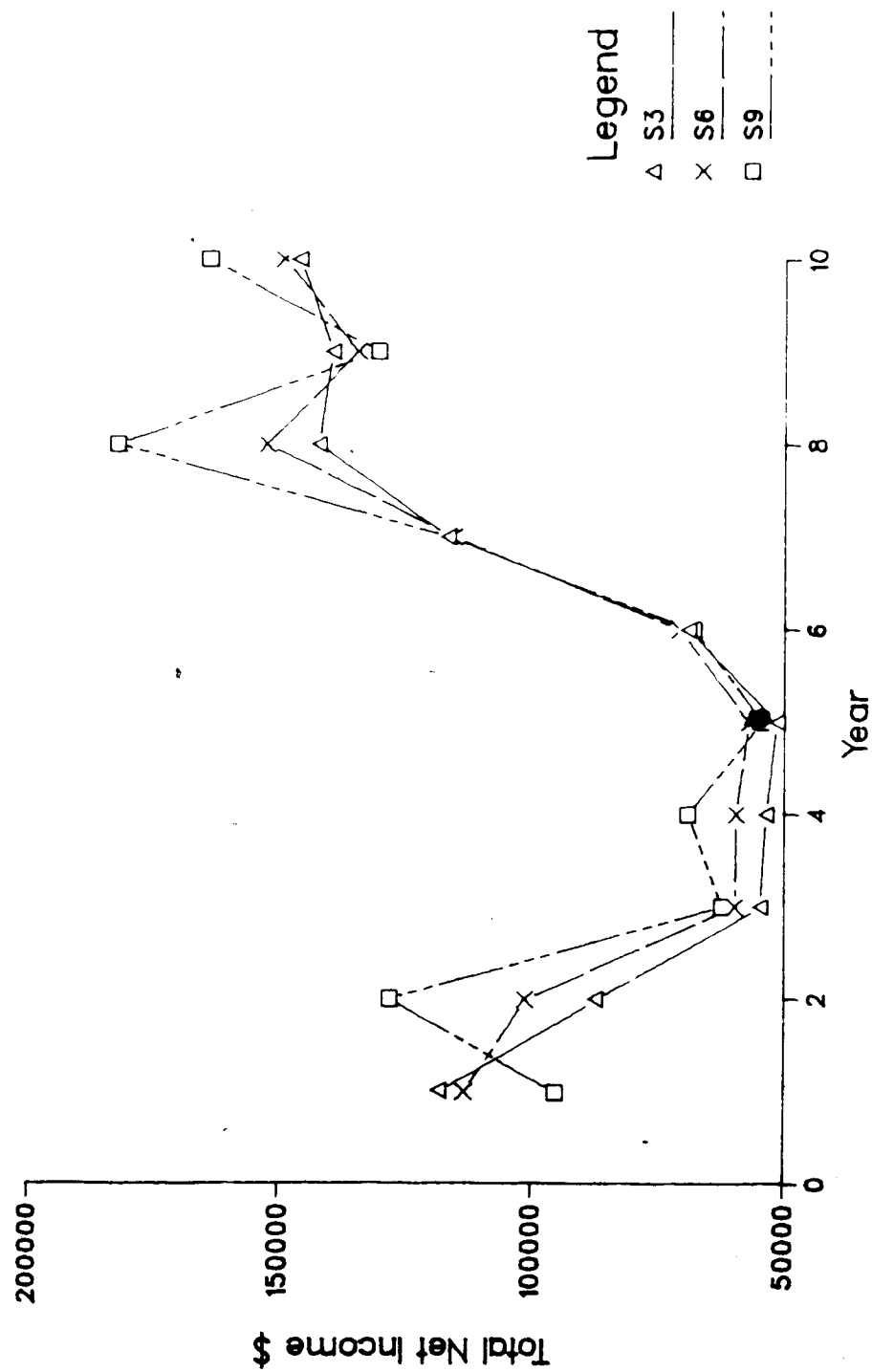
TABLE 5.30

Average Fertilizer and Herbicide Costs per Crop Area for Dominant Strategies ($/crop acre)

	Strategy		
	S3	S6	S9
Fertilizers	14.4	17.0	19.5
Herbicides	9.2	14.8	16.3

Fertilizer costs per crop acre for the 1/3-2/3 cropping system and continuous cropping system averaged 18% and 35% higher than for the 1/2-1/2 cropping system. Similarly, herbicide costs for the same rotations averaged 60% and 77% higher than for the 1/2-1/2 cropping system. These results are consistent with the expectation that increased fertilizer and herbicide requirements are associated with more intensive cropping systems.

Labour Requirements

The total labour and the seasonality of labour requirements varied considerably with the type of cropping program practiced.

Table 5.31 shows the average labour requirements, both permanent and hired for the three dominant strategies.

TABLE 5.31

Average Labour Requirements for Dominant Strategies

	Strategy		
	S3	S6	S9
Labour (hrs.)	996	1096	1340

Labour requirements refer only to the hours of machinery use and does not include management time or any other labour associated with operating the farm unit. This may vary for the different strategies, but is not considered to be a big factor.

Labour requirements for the 1/3-2/3 and continuous cropping systems averaged 10% and 34% greater respectively than for the 1/2-1/2 cropping program. The continuous cropping rotation required about 345 more hours of machinery time than the 1/2-1/2 rotation. Moreover, labour requirements appear to be more uniformly distributed throughout the year for the 1/2-1/2 and the 1/3-2/3 cropping programs than the continuous cropping program (Fig. 5.7). Labour requirements for the continuous cropping operation are concentrated during seeding and harvest periods and consequently required significant increases in labour during the spring and fall periods. All the hired labour was used during these two periods.

Machinery Requirements

Substantial differences in machinery requirements were observed between the three strategies. Over the ten year period of simulation, with the restrictions imposed on machinery purchasing and selling policies as described earlier, the 1/2-1/2 cropping program required the purchase of a new 28 foot cultivator, with all other machinery listed in the beginning inventory being sufficient to operate the

Figure 5.7

Monthly Labour Requirements for Dominant Strategies
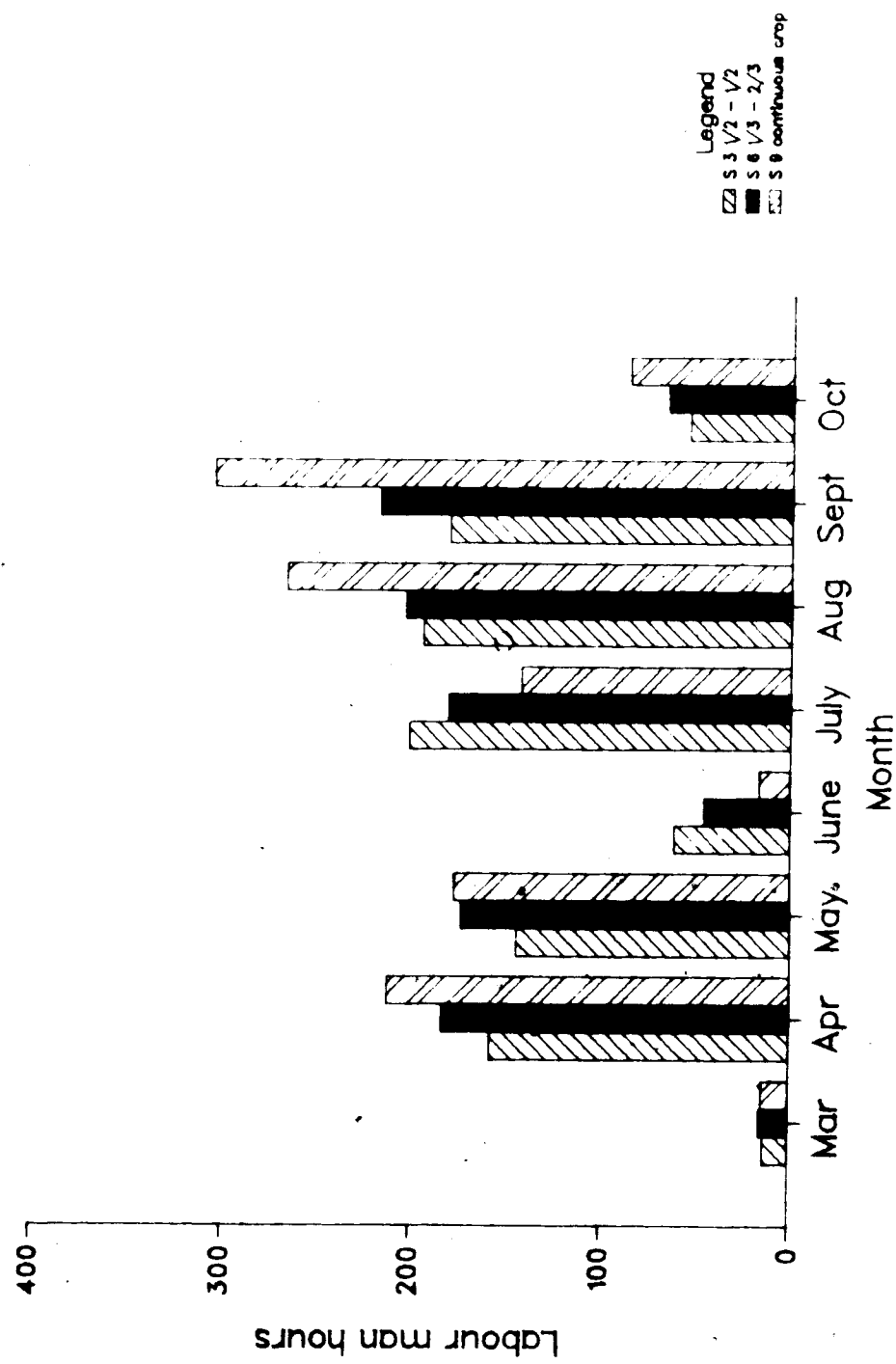
farm over this period. For the 1/3-2/3 cropping system, the case farm required the additional purchase of a new 28 foot discer, a new 28 foot cultivator and a new 48 foot rodweeder.

The continuous cropping operation would require the purchase of all the above machinery and a new 18 foot P.T.O. swather. No new tractors were purchased for the continuous cropping operation since the case farm starts off in a situation where there is sufficient horsepower to complete all field operations on time for all three strategies. This suggests that the case farmer with his existing 1/2-1/2 cropping system has excess horsepower on the farm.

Price Sensitivity Analysis

A series of experiments were conducted to determine how the mean expected equities and associated variances of the three dominant strategies S_3, S_8 and S_9 would change with increases in output prices. Accordingly, output prices were allowed to increase from 10% to 50% above the mean price, with yields remaining stochastic. The expected equities and standard deviations are shown in Table 5.32 and illustrated in E-V space as in Fig. 5.8.

The results indicate that at higher grain prices, continuous cropping becomes more attractive. For example, when grain prices are 50% higher than the mean, moving from a 1/2-1/2 to a continuous cropping operation for the ten years, results in an increase in expected equity of $103,611

TABLE 5.32

Means and Standard Deviations of Expected Ending Equities
with Increasing Output Prices and Variable Yields

Scenario	Strategy	Mean Equity	Standard Deviation($)
Constant Average Price	S3	1,498,438	6289
	S6	1,500,674	6575
	S9	1,513,492	9690
10% Higher Prices	S3	1,562,391	5657
	S6	1,567,548	6310
	S9	1,595,483	9255
20% Higher Prices	S3	1,625,918	5325
	S6	1,633,984	6226
	S9	1,677,025	9037
30% Higher Prices	S3	1,687,965	5019
	S6	1,699,034	6293
	S9	1,756,771	8793
40% Higher Prices	S3	1,749,434	4825
	S6	1,763,627	6162
	S9	1,836,005	8525
50% Higher Prices	S3	1,810,223	4561
	S6	1,827,591	6157
	S9	1,913,834	8701

Figure 5.8

Means and Standard Deviations of Expected
Ending Equities With Increasing Output Prices and Variable Yields
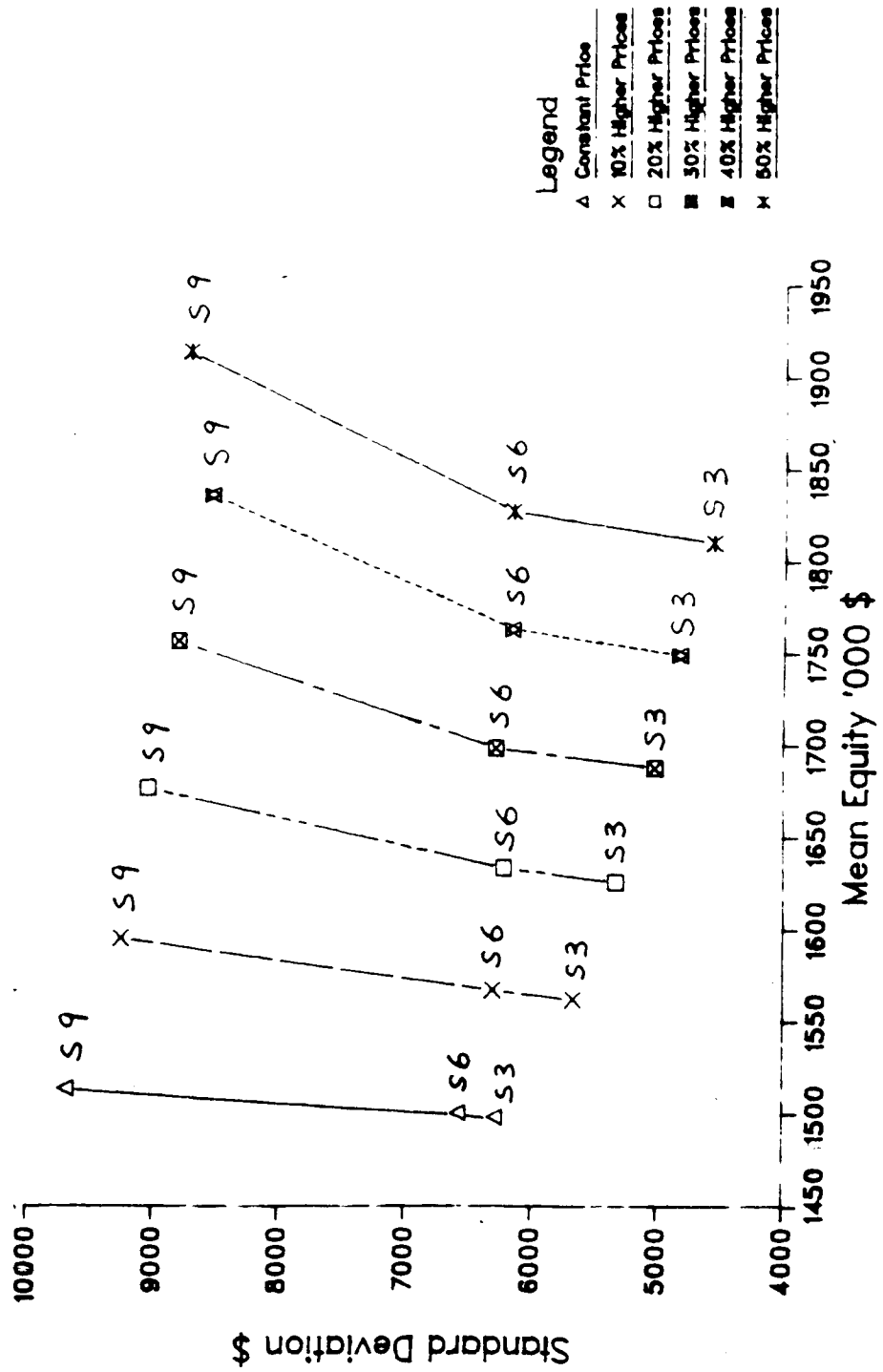
(5.7%), with an associated increase in risk of $4,140 (90.8%). The relatively small value of the coefficient of variation associated with a continuous cropping operation at 50% higher grain prices (0.45%) indicates however that in absolute terms, there is only a marginal increase in risk. It is worth noting that 50% above the base prices is a fairly good representation of what grain prices were during 1981. Furthermore, continuous croppers in the study area claim that high grain prices coupled with high stubble/fallow yield ratios (greater than 0.7) during the period 1979-1981 convinced them of the economic rationality of continuous cropping. Generally, as grain prices increase, continuous cropping becomes less risky and has a higher expected pay-off. Also, as grain prices increase, the expected equities for S_3 and S_6 also increase, while the standard deviations decrease or remain about the same, indicating that price variablilty is an important contributer to overall risk in farming. Furthermore, increasing output prices do not change the relative positions of the three different cropping programs, with continuous cropping remaining the riskiest of the three.

If a 1/2-1/2 cropping program is maintained, even at higher grain prices, such as a 50% increase in output price, there is still a substantial gain in equity with a large drop in the level of risk making S_3 a very "safe" cropping system.

Thus, this analysis shows that the type of cropping program that will be chosen even at high grain prices depends upon the level of risk aversion of the individual producer. However, even the more risk averse producer will be more likely to move toward continuous cropping with higher output prices.

Yield Sensitivity Analysis

Another series of experiments were conducted to determine whether the relative positions of the three dominant strategies S_3, S_4 and S_5 would change, with increasing stubble/fallow yield ratios. [73] Accordingly, stubble yields were allowed to increase from 60% of fallow yields to 80% of fallow yields, while output prices were kept constant at the mean (1972-81). The expected ending equities and their standard deviations are shown in Table 5.32.

Representing them in E-V space gives a clear indication of the relative positions of the different strategies as shown in Fig. 5.9.

When stubble yields are 60% of fallow yields, with output prices remaining constant at the mean, S_3 appears to be the dominant strategy. Under these conditions, continuous cropping pays less and is more risky than a 50-50 operation. When stubble yields are 65% of fallow yields, the results

[73] For the case farmer, stubble yields were approximately 70% of fallow yields calculated as an average over the ten year period 1972-1981.

TABLE 5.33

Means and Standard Deviations of Expected Ending Equities
for Increasing Stubble/Fallow Yield Ratios

Stubble/Fallow Yield Ratio	Strategy	Mean Equity ($)	Standard Deviation ($)
	S3	1,499,275	7,450
0.6	S6	1,433,159	8,086
	S9	1,299,275	10,777
	S3	1,499,275	7,450
0.65	S6	1,467,208	8,307
	S9	1,403,035	10,663
	S3	1,499,275	7,450
0.7	S6	1,500,484	8,334
	S9	1,501,443	10,578
	S3	1,499,275	7,450
0.8	S6	1,564,932	8,415
	S9	1,685,543	11,311

Figure 5.9

Means and Standard Deviations of Expected
Ending Equities With Constant Output Prices and
Increasing Stubble—Fallow Yield Ratio

Legend
△ 0.6 S/F Y Ratio
✕ 0.65 S/F Y Ratio
□ 0.7 S/F Y Ratio
⊠ 0.8 S/F Y Ratio
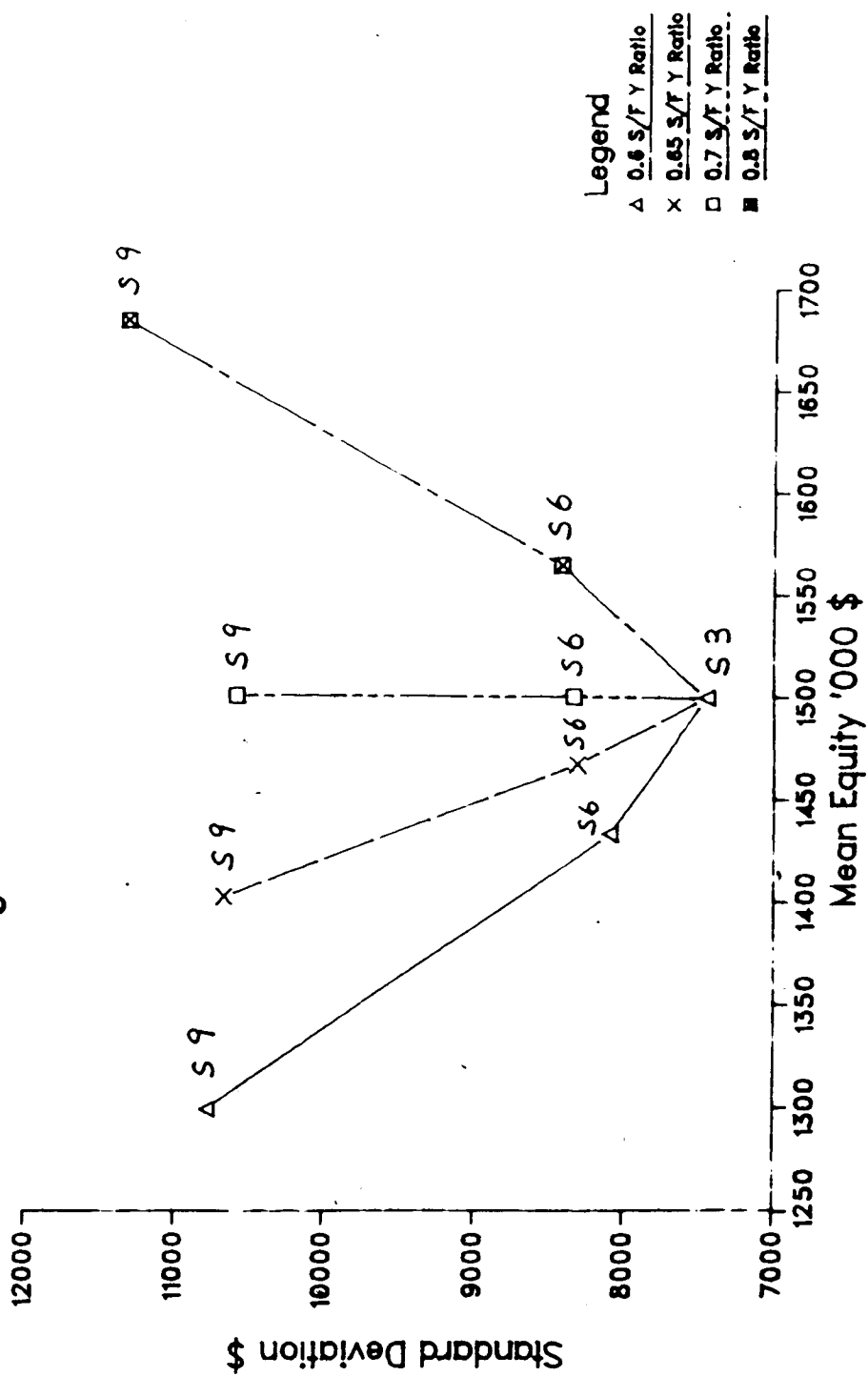
are similar. The break-even point at which the expected equities are all approximately alike with varying degrees of risk occurs when stubble yields are 70% of fallow yields. At this point, a risk neutral individual would be indifferent between the three strategies. A risk averse individual would choose S_3 over S_6 and S_9 since it pays the same with less risk. A risk prefering individual however, would prefer S_9 over S_3 and S_6. When stubble yields are 80% of fallow yields, continuous cropping (S_9) becomes more attractive. At this point, continuous cropping will give an increase in expected equity of $186,269 over a 50-50 program and is associated with a small ($3,861) increase in risk. Which program is chosen will again depend upon the level of risk aversion of the individual producer.

VI. SUMMARY AND CONCLUSIONS

This study has attempted to address the problem of identifying the relative profitability of different cropping systems and the related risks, in the Dark Brown Soil Zone of Alberta. The objective was to determine whether it is technologically and economically feasible to reduce fallow acreages and thereby increase net farm incomes and overall agricultural production. The impact of changing key economic variables and the resulting economic outcomes at the farm level are examined using simulation methodology.

The study has focused primarily on the evaluation of different management strategies, over a period of time using mean equity values and related variances as the criteria for ranking of these strategies.

This chapter will summarize findings of the study and discuss their implications. Furthermore, limitations of the study are pointed out, and suggestions are made for further research.

A. General Summary

The general objectives of this study were to examine the economic consequences at the farm level, of increasing or decreasing summerfallow acreages in the Dark Brown soil zone of Alberta, and to identify the main factors affecting the farm operator's decisions on selection of cropping systems.

The study has relied heavily upon stochastic dominance concepts to identify the relative positions of different cropping systems. These theoretical considerations are dealt with in Chapter 2. A brief review of relevant literature follows in Chapter 3, focussing mainly on the technological developments that have a bearing on relative profitability of different cropping programs. Several economic studies related to the problem are also outlined and discussed.

Chapter 4 discusses data requirements and data sources for the study. It also includes a discussion of the methodology used and a detailed account of the simulation model which was employed as a central analytical tool in the study.

The results obtained from the analysis of crop yields, the farm survey, and case farm simulation are presented and discussed in Chapter 5. The analysis of long term crop yields provides some indication of the relationship between stubble and fallow crop yields in the study area for the period, 1972-1981. The effects of soil characteristics and management strategies on crop yields are also analyzed and provide an indication of the relative importance of these factors in the overall consideration of cropping program selection. The farm survey was an indicator of the general characteristics of producers following diverse crop management strategies. Although requiring more quantitative analysis, it proved useful in identifying the differences in key economic parameters and production coefficients

associated with the different cropping programs. The survey
also enabled the careful selection of a case farm, which was
subsequently simulated over a ten year period. Evaluation of
different management strategies was accomplished using E-V
analysis techniques outlined in Chapter 2. Chapter 5
contains the details of the analysis procedures and the
results obtained.

B. Analysis of Crop Yields

The results of the crop yield analysis indicates that:

1. There are yield differences between agro-cliomatic
   zones, ClI classes and subclasses and these therefore
   should be important considerations in the selection of
   cropping programs at the farm level.

2. Stubble crop yields in the study area have been
   exceptionally high during the period 1972-1981, compared
   to provincial averages and could be one reason for the
   growing popularity of more intensive cropping systems.
   However, the greater variability of stubble crop yields,
   with a tendency to be exceptionally poor in low moisture
   years, is clearly evident and becomes an important
   consideration of producers wishing to crop more
   intensively.

3. The effect of higher yields resulting from addition of
   fertilizer is clearly evident, although the data did not
   permit the analysis of crop yield correlations with
   amount of fertilizer added.

C. Reasons for Summerfallow

The farm survey revealed the diversity of farmers in the study area with respect to stubble and fallow crop management practices. The survey on producers' opinions and beliefs regarding cropping programs revealed several interesting insights about the decision-making process at the farm level. Weed control, moisture conservation and income stability are the primary reasons why farmers in the survey sample choose to summerfallow. Although producers in the study area are well aware of the negative effects of summerfallowing, short run economic considerations appear to influence their decision to summerfallow.

The majority of producers agree that technological improvements and high stubble crop yields in recent years have tended to encourage more intensive cropping but low and variable grain prices coupled with uncertainty of markets for their products remain serious concerns. Thus, meaningful projections of increased agricultural production due to summerfallow reduction should consider these countervailing forces, because in the final analysis, it is the farmers who decide how much to grow and how much to summerfallow.

D. Payoff and Risk of Different Cropping Programs

The case farm simulation provided the means to evaluate different management strategies and identify specific differences in equity positions, riskiness and resource requirements of these strategies. In all, 12 different

strategies were evaluated. The general conclusion is that for all situations, the inclusion of custom work is an inferior strategy to purchasing new or used machinery when more land is being brought into production. Also, at the farm level, producers may find difficulty in getting good custom operators as and when they require them.

Continuous cropping does result in higher payoffs than other cropping programs but is always associated with higher risk. This is the case for both situations when prices and yields are allowed to vary and when prices are constant at the mean with varying yields.

Higher output prices do make continuous cropping seem more attractive but again it does not dominate other cropping systems because it is riskier. High grain prices coupled with stubble/fallow yield ratios greater than 0.7 will likely induce a substantial reduction in summerfallow acreages. By doing so however, a producer is still faced with higher risk. As the farm survey reveals, producers will likely reduce summerfallow acreages by up to 20% if the above situation prevails. However, risk-averse producers who are more concerned with survivability of their operation are more likely to stick to a safe cropping program such as a 1/2-1/2 operation, rather than accept the greater risk of more intensive cropping.

The sensitivity analysis reveals that price risk seems to be a more dominant factor than yield risk, contributing to the overall problem of uncertainty.

E. Resource Requirements

The study reveals that resource requirements and their timing, vary with cropping intensity. Thus, continuous cropping does require a greater investment in machinery than other cropping systems.[*] In addition, machinery replacement policy at the farm level can affect the profitability of the operation, regardless of the cropping intensity. Replacing machinery at 13% remaining useful life is a superior strategy to replacing machinery at 50% or 66% remaining useful life. At the farm level therefore, it appears that a machinery replacement policy that emphasizes longer use of existing machinery is more prudent than frequent purchases or replacements. Although it was not possible in the simulation to defer machinery purchase in low income years due to model constraints, it is evident that in a continuous cropping operation, machinery tends to be replaced faster due to greater use.

Producers wishing to go into continuous cropping can expect to be using more fertilizers and chemicals and thus incur higher costs per acre, but as the analysis shows, these costs are likely to be somewhat less than twice as much if one is moving from a 1/2-1/2 to a continuous cropping program. In addition, labour requirements are significantly higher for the continuous cropping operation as compared to the other systems. This extra labour is

---

[*]The greater investment is due to the bigger machinery required for continuous cropping as revealed by the simulation. Furthermore, operating costs are also higher. Similar conclusions are drawn from the farm survey.

required primarily during the seeding and harvesting operations. This fact would be an important consideration of producers in areas where the availability of skilled farm labour is limiting.

The study reveals that producers' concerns about stubble yields not being sufficiently high or reliable to make continuous cropping more profitable than less intensive cropping systems, is well founded. When stubble yields are less than 70% of fallow yields and when grain prices are low, the 1/2-1/2 rotation dominates all other rotations.

F. Implications for Census Division 5

At the case farm level, moving from a 1/2-1/2 to a 1/3-2/3 cropping program, results in a 14.8% increase in crop production. Moving from a 1/3-2/3 to a continuous cropping operation, results in a 22.3% increase in crop production (Table 5.34.). These are significant increases in production due to summerfallow reduction.

In 1981, there were 1,766,000 acres of cropped land and 907,000 acres in summerfallow in Census Division 5. Thus, the average rotation in Census Division 5 was the 1/3-2/3 rotation. Extending the case farm results to the Census Division suggests that, if farmers were to move from their present 1/3-2/3 cropping program to a continuous cropping program, this could result in a 22.3% increase in crop production.

TABLE 6.1

The Effect of Increasing Cropping Intensity on Crop Production

	Acres in Fallow	Wheat on Stubble	Wheat on Fallow	Barley on Stubble	Barley on Fallow	Rape on Fallow	Rape on Stubble	Total Value ($)
1/2 – 1/2	550		333		111	111		
yield/acre (bu)	0		45		70	27.7		
price/bu ($)	0		5.51		2.70	7.25		
Total Val. ($)	0		82567		20979	22291		125837
1/3 – 2/3	360	222	222	148		148		
yield/acre (bu)	0	33.5	45	46.8		27.7		
price/bu	0	5.51	5.51	2.70		7.25		
Total Val. ($)	0	40977	55044	18701		29722		144444
Continuous Cropping	0	666		222			222	
yield/acre (bu)	0	33.5		46.8			16	
price/bu ($)	0	5.51		2.70			7.25	
Total Val. ($)	0	122933		28051			25752	176736

These are crude estimates that may not adequately reflect the impact of rising input costs on total production. However, they provide some indication of the increased crop production that may be expected with increasing cropping intensity. Predicting reductions in summerfallow acreages resulting in increased production is a hazardous task due to the thousands of individual farm decision makers involved.

G. Areas For Future Research

This study has relied heavily on the use of a computer simulation model to reflect the economic outcomes at the farm level of different crop management strategies. Several suggested improvements to the model are outlined in Chapter 4. While the effects of output price changes and yields on the relative profitability of different cropping programs have been researched in some detail, input price change effects have been largely ignored. The combined effect of input and output price changes on the economic outcomes at the farm level of increasing or decreasing cropping intensities requires further research. Furthermore, it would have been preferable to use a longer yield series to generate a series of random yields, but lack of data at the case farm level, prior to 1972, precluded this possibility.

Technological improvements such as snow management techniques, although discussed in the study, have not been adequately simulated due to model limitations. In actuality,

a continuous cropper would probably be using a combination
of methods to improve his stubble yields. Further research
is required on the direct impact of such new technology o'n
crop yields.

Institutional factors such as changes in grain quota
policies and government programs, and their effects on
cropping intensities, have not been given much prominence in
this study. Indeed, if farmers are sensitive and responsive
to such factors, they may well be induced to substantially
alter their cropping practices and again this aspect
requires further research.

BIBLIOGRAPHY

Agriculture Canada, "Selected Agricultural Statistics for Canada and the Provinces", Ottawa, 1982.

Anderson, C.H. "Comparision of Tillage and Chemical Summerfallow in a Semi-Arid Region", *Can. J. Soil Sci.*, 51:397-404, 1971.

Anderson, D.T., "Surface Trash Conservation with Tillage Machines", *Can. J. Soil Sci.*, 41:99-114, 1961.

Anderson, J.R.., "Simulation: Methodology and Application in Agricultural Economics", *Rev. Mktg. Agric. Econ.*, 42(1):3-55, 1971.

Anderson, J.R.; John L. Dillon and J. Brian Hardaker, **Agricultural Decision Analysis**, (Ames, Ia: The Iowa State University Press, 1977).

Anderson, M. "Factors Affecting Summerfallow Acreage in Alberta", (Edmonton: Environment Council of Alberta, August 1981).

Ausenhus, C. "Does Summerfallow Pay?" *Agdex* No. 821-6, Farm Business Management Branch. Alberta Department of Agriculture, 1977.

Austenson, H.M.; A. Wenhardt and W.J. White, "Effect of Summerfallowing and Rotation on Yield of Wheat, Barley and Flax", *Can. J. Plant Sci.*, 50:659-666, 1970.

Austenson, H.M. and S.R. Khatri, ng "Relative Yields of Wheat, Barley and Oat Cultivars on Summerfallow and Stubble Land", *Can. J. Plant Sci.*, '52:891-895, 1972.

Bauer, A. " Evaluation of Fallow to Increase Water Storage for Dryland Wheat Production", *North Dakota Farm Research Report*, 25:6-9, 1968.

Bauer, L. "A Quadratic Programming Algorithm for Deriving Efficient Farm Plans in a Risk Setting", Ph.D. Dissertation, Oregon State University, June 1971, pp. 28-30.

Bauer, L., T.A. Peterson and T.J. Lougheed, "The Farm Management Field Laboratory: Its Concept and Objective and the 1980 Business Summary", Department of Rural Economy, University of Alberta, Nov. 1981.

Bentley, C.F., "Agricultural Changes and Resource Endowments", *Agriculture and Forestry Bulletin,* Fall 1977. pp9-17.

Bentley, C.F.,"Problems and Opportunities in Western Canadian Agriculture", In *Challenges and Opportunities in Saskatchewan Agriculture, Science Council Background Study 1,* Saskatchewan Science Council, Saskatoon, 1978. pp 67-74.

Bole, J.B., and U.J. Pittman, "Spring soil Water, Precipitation and Nitrogen Fertilizer: Effect on Barley Yield", *Can. J. Soil Sci.,* 60:461-469, 1980.

Burt, O.R., and M.S. Stauber, "Dryland Cropping Strategies to Prevent Saline Seep", *Proceedings of Regional Saline Seep Symposium, Bulletin No. 1132.,* Cooperative Extension Service, Montana State University, Bozeman, April 1976.

Caprio, J.M.; G.K. Grunwald and R.D. Snyder, "Snow Barrier Potential for Harvesting Moisture in Transects Across Chinook Areas in Montana", Montana Agricultural Experiment Station, Research Report No. 175, Montana State University, Bozeman, February, 1982, pp 2.

Clayton, J.S.; W.A. Ahrlich,; D.B. Cann, J.H. Day and I.B. Marshall, "Soils of Canada", Canada Department of Agriculture. Vol. 1:104, 1977.

Capel, R.E., "Predicting Wheat Acreage in the Prairie Provinces", *Can. J. Agric. Econ.,* 16(2):87-89, 1968.

Country Guide, "Fallow Yields on Stubble", August 1983, pp 38.

Dent, J.B., and J.R. Anderson, eds., **Systems Analysis in Agricultural Management,** (Sydney: John Wiley and Sons, Australasia Ltd., 1971).

Dew, D.A., "Effect on Summerfallow Tillage on Soil Physical Properties and Yield of Wheat", *Can. J. Soil Science, 48:21-26, 1968.*

Dillon, J.L., **The Analysis of Response in Crop and Livestock Production,** 2nd ed. (Oxford: Pergamon Press, 1977).

Doll, J.P. and F. Orazem, **Production Economics, Theory with Applications,** (Grid Inc., Columbia, Ohio, 1978).

Erbach, D.C., "Planting for Crop Production with Conservation", In *Proceedings of the American Agricultural Engineers Conference on Crop Production with Conservation in the 80's, A.S.A.E.*, St. Joseph, Michigan, December 1980.

Ferguson, H., and J. Krall, "Crop Production Systems in Arid and Semi-Arid Cool Temperate Zones", In **Soil, Water and Crop Production**, D.W. Thorne and M.D. Thorne eds. 1979.

Grallaher, R.N., "Multiple Cropping Minimum Tillage", *Florida Cooperative Extension Service, Bulletin, MMT-1*, Institute of Food and Agricultural Science, University of Florida, Gainseville, Florida, 1980.

Grainews, "Wheat-Fallow System Sometimes Pays - North Dakota." Farm Information Services, United Grain Growers Ltd., Aug. 1980.

Grainews, "To Seed or Not to Seed Stubble", Farm Information Services, United Grain Growers Ltd., September 1981.

Grainews, "Summerfallow - The Alternative", Farm Information Services, United Grain Growers Ltd., January 1982. .

Halter, A.N., and G.W. Dean, **Decisions under Uncertainity with Research Applications**, (Cincinnati: South-Western Publishing Co., 1971).

Heady, E.O., and J.L. Dillon, **Agricultural Production Functions**, (Ames, Ia.: The Iowa State University Press, 1961).

Hedlin, R.A., "The Place of Summerfallow in Agriculture on the Canadian Prairies", in *Prairie Production Symposium: Soils and Land Resources*, (Saskatoon: The University of Saskatchewan, October 29-31, 1980).

Johnson, W.E., "Conservation Tillage in Western Canada", *In Conservation Tillage: Problems and Potentials, Soil Conservation Society of America, Special Publication* No. 20, 1977.

Johnson, L.M., "Economic Analysis of Crop Rotations in Western Canada", *Can. Farm. Econ.*, 13(5), Oct. 1978.

Johnson, R.G., and M.B. Ali, "Economics of Wheat-Fallow Cropping Systems in Western North Dakota", **West. J. Ag. Econ.**, 7(1): 67-77, July 1982.

Kaliel, D.A., "Farm Enterprise Selection Under Risk", M.Sc. Dissertation, University of Alberta, Oct. 1982.

Knight, D.A., "Economic Considerations for Selecting the Superior Frequency of Fallow for Wheat in Three Locations in Western Kansas", *Agricultural Experiment Station, Technical Bulletin 85,* Kansas State College, Manhattan. September 1956.

Knight, F.H., **Risk, Uncertainity and Profit,** (New York: Sentry Press, Jan. 1921).

Koronka, P., "Machinery Development for Direct Drilling", *Outlook Agriculture* 7(4): 190-195, 1973.

Krall, J., A. Dubbs, and W. Larsen, "No-till Drills for Recropping", *Montana Agricultural Experiment Station, Bulletin 716.* Montana University, Bozeman, 1979.

Leavitt, F.D., "Research on the Control of Canada Thistle in Alberta", Prepared for the Canada Thistle Symposium, Regina, January 1980.

Love, H.C.; "Crop Production Risk in Alberta", *Agricultural Economics Research Bulletin* No. 5, University of Alberta, Edmonton, June, 1970.

Mackenzie, J.G., "Economics of Grain-Fallow Rotations and Fertilizer Use in the Prairie Provinces", *Can. Farm. Econ.,* 3(3): 15-27, Aug. 1968.

Mackenzie, J.G., "Fallow Versus Stubble Yields", *Can. J. Plant Sci.,* 50: 659-666, 1970.

Michalyna, W., and R.A. Hedlin, "A Study of Moisture Storage and Nitrate Accumulation in Soil, as Related to Wheat Yields on Four Cropping Sequences", *Can. J. Soil Sci.,* 45: 5-15, 1961.

Molberg, E.S.; E.V. McCurdy; A. Wenhardt; D.A. Dew, and R.D. Dryden, "Minimum Tillage Requirements for Summerfallow in Western Canada", *Can. J. Soil Sci.,* 47: 211-216, 1967.

Monney, B.G., "An Evaluation of Farm Management Strategies under Drought Conditions: The Case of Dryland Grain Production on the Prairies", Ph.D. Dissertation, University of Alberta, June 1983.

Morrison, J.E., and C.F. Abrahms, "Conservation Tillage Opener for Planters and Transplanters", *A.S.A.E. Transcript* 21 No 4: 843-847.

Penny, D.C. "Agricultural Land - A Renewable Resource?", *Farm Light and Power,* March 1980.

Peters, T.W. and W.W. Pettapiece, "Crop Yields in Alberta: Preliminary Relationships to Soil Capability for Agriculture and Soil Type", *Alberta Institute of Pedology*, Contribution No. M-81-1, 1981.

Phillips, R.E., R.L. Blevins, G.W. Thomas, W.W. Frye, and S.H. Phillips, "No-Tillage Agriculture", *Science* 208(4448): 1108-13, 1980.

Rennie, D.A., "Soil, The Threatened Resource", in *Challenges and Opportunities in Saskatchewan Agriculture, Science Council Background Study 1*, Saskatchewan Science Council, Saskatoon, 1978.

Rennie, D.A., "Long Term Effects of Intensive Farming", *Farm, Light and Power*, March 1980.

Robertson, G.W., "Wheat Yields for 50 Years at Swift Current, Saskatchewan in Relation to Weather", *Can. J. Plant Sci.*, 54: 625-650, 1974.

Siemans, L.B., "Cropping Systems, an Evaluative Review of the Literature", *University of Manitoba Technical Bulletin* No. 1, 1963.

"The Grain Grower", Farm Information Services, *United Grain Growers*, Jan. 1976, pp. 100-126.

"The Grain Grower", Farm Information Services, *United Grain Growers*, June 1978, pp. 100-126.

"The Grain Grower", Farm Information Services, *United Grain Growers*, Oct. 1978, pp. 100-100.

The Manitoba Cooperator, "Summerfallow Damaging Prairie Farmland", Aug. 14th, 1980.

The Western Producer, "Billions Wasted Unless Soil Saved", Jan. 20th, 1983.

Thorne, D.W., and M.D. Thorne, eds., **Soil, Water and Crop Production**, 1979.

von Neumann, J., and O. Morgenstern, **Theory of Games and Economic Behaviour**, (Princeton: Princeton University Press, 1947).

Weaver, G.D., M.J. Nilsson and R.E. Turney, "Prospects for the Prairie Grain Industry 1990", Canada Grains Council Research Report, Nov., 1982.

Willams, D.A., "Tillage as a Conservation Tool", in *Tillage for Greater Crop Production, Proceedings of the American Agricultural Engineers Conference on Crop Production with Conservation in the 80's, A.S.A.E.* St. Joseph, Michigan, Dec. 1980.

Williams, G.D.V., "Estimates of Prairie Provincial Wheat Yields Based on Precipation and Evapotranspiration", *Can. J. Plant Sci.*, 53: 17-30, 1973.

Young, D.L., "Risk Preferences of Agricultural Producers: Their Use in Extension and Research", *Washington College of Agricultural Research Centre, Scientific Paper* No. 5395, 1979.

Young, R.A., "Can Nitrogen Fertilizer and Modern Weed Control Methods Eliminate Summerfallow?", *North Dakota Agricultural Experiment Station Bulletin* No. 20, 1958.

Zentner, R.P., B.H. Sonntag and G.E. Lee, "A Simulation Model for Dryland Crop Production in the Canadian Prairies", *Agricultural Systems*, 3(4): 241-257, 1978.

Zentner, R.P., and C.W. Lindwall, "An Economic Assessment of Zero Tillage in Wheat-Fallow Rotations in Southern Alberta", *Can. Farm Econ.*, 13(6): 1-6, Dec. 1978.

Zentner, R.P., B.H. Sonntag, J.B. Bole and U.J. Pittman, "An Economic Assessment of Dryland Cropping Programs in the Prairie Provinces: Expected Net Incomes and Resource Requirements", *Can. Farm Econ.*, 14(4): 8-19, Aug. 1979.

Zentner, R.P., B.H. Sonntag, J.B. Bole and U.J. Pittman, "An Economic Assessment of Dryland Cropping Programs in the Prairie Provinces: Income Variability", *Can. Farm Econ.*, 14(6): 9-19, Dec. 1979.

Zentner, R.P., "Prairie Agricultural Farm Simulators (PAFS): A Documentation of the Dryland Crop Enterprise Model", Agriculture Canada Research Station, Current, Saskatchewan. (mimeographed), 1981.

Zentner, R.P., and R.M. Koroluk, "An Introduction to a Whole Farm Computer Model of Dryland Grain Production for Western Canada", Agriculture Canada Research Station, Swift Current, Saskatchewan, (mimeographed), 1982.

Zentner, R.P., C.A. Campbell, D.W.L. Read and C.H. Anderson, "First 12 Years of a Long-Term Crop Rotation Study in Southwestern Saskatchewan - Economic Considerations", Agriculture Canada Research Station, Swift Current, Saskatchewan. (mimeographed), 1983.

APPENDIX I: QUESTIONNAIRE

THE ECONOMICS OF CONTINUOUS CROPPING IN THE DARK BROWN SOIL ZONE OF ALBERTA

1. Name of Operator .... 2. Age ....

3. Land Location (home Quarter) ....

4. Mailing Address ....

5.

FARM CASH SALES 1981 ($)

Crops	Beef	Hogs	Other	Total
_____	_____	_____	_____ =	_____

6. How much land did you farm in 1981?

Type	Acres Owned	Rented Crop Share	Rented Cash Rent	Total
Cereal Crops				
Oil Seeds				
Forages				
Fallow				
Tame Pasture				
Native Pasture				
New Breaking				
Farmstead				
Other				
Total				

7. What labour was spent on cropland in 1981 to the nearest workday?

Person	Age	Sex	J	F	M	A	M	J	J	A	S	O	N	D	Total
Operator															
Spouse															
Children															
Hired															
Casual															
Total															

Cost (Hired Labor) = _____

Cost (Casual Labor) = _____

Custom Work Hired/Done for Others in 1981

	Hired		Done for Others	
Operation	Acres	Cost	Acres	Revenue
Seeding				
Spraying				
Fertilizing				
Combining				
Other				
Other				
Other				
Total				

Machinery Availability and Use in 1981

Item	Size	Year of Purchase	Purchase Price
A. Tillage andPlanting Machinery			
Cultivator			
Blade			
Double Disc			
Rod Weeder			
Harrow			
Packers			
Discer			
Hoe Drill			
Press Drill			
Air Seeder			
Grain Dryer			
Rock Picker			
Sprayer			
Herbicide Applicator			
Fertilizer Applicator			
B. Harvest Machinery			
Swather PTO			
Swather SP			
Combine PTO			
Combine SP			
Truck			
Truck			

Item	Size	Year of Purchase	Purchase Price
Trailer			
Auger			
Tractors			

Buildings

Grain Storage

Machinery Storage

Other

Other

9. Starting Date of Spring Operations in 1981 _____

10A. Land Preparation and Seeding of Stubble in 1981

Fall Ops After 1980		Spring Ops Prior to Seeding				Seeding	Post Seed Tillage/Spraying Ops					Harvest Ops
1st Op	2nd Op	1st Op	2nd Op	3rd Op	4th Op		1st Op	2nd Op	3rd Op	4th Op	1st Op	2nd Op

Is this the usual practice? _____

B. Land Preparation and Seeding of Fallow Land 1981

Fall Fertilizing/ Herbicide App.		Spring Ops Prior to Seeding				Seeding	Post Seed Tillage/ Spraying Ops					Harvest Ops
1st Op	2nd Op	1st Op	2nd Op	3rd Op	4th Op		1st Op	2nd Op	3rd Op	4th Op	1st Op	2nd Op

Is this the usual practice? _____

C. Preparation of Summerfallow in 1981 _____

Spring, Summer and Fall Operations						
1st Op	2nd Op	3rd Op	4th Op	5th Op	6th Op	7th Op

Is this the usual practice? _____

CODE
1 Cultivate & Harrow
2 Disc and Harrow
3 Cultivate & Rodweed
4 Cultivate
5 Harrow and Rodweed
6 Double Disc
7 Disc
8 Blade
9 Sprayer
10 Banding
11 Fertilizing
12 Spreading
13 Press Drill
14 Hoe Drill
15 Air Seeder
16. Swathing
17. Combining
18. Harrowing
19. Rodweed

11. Have there been any changes in your tillage practices in the last 5 years?

Please explain ....

12. What is the soil texture for your farm?

Sandy   Sandy Loam   Sandy Clay Loam   Loam   Clay Loam   Clay

13. How would you rate the moisture of the seedbed prior to seeding for 1981?

	1 Dry	2 Adequate	3 Excellent	4 Too Wet
Stubble				
Fallow				

14. Herbicide & Insecticide Expenditure in 1981

Crop	ST	FAL	Kind of Herbicide/ Insecticide	Rate /acre	Cost /unit
Wheat					
Barley					
Oats					
Rye					
Rape					
Flax					
Mustard					
Other					

15. Fertilizer Use (in lbs/acre)

Crop	1981				1980				1979				1978			
	ST		FAL		ST		FAL		ST		FAL		ST		FAL	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
Wheat																
Barley																
Oats																
Rye																
Rape																
Flax																
Mustard																
Other																

K = KIND
Q = QUANTITY

16. Crop Yields (in bu./acre)

Crop	1981 ST	1981 FAL	1980 ST	1980 FAL	1979 ST	1979 FAL	1978 ST	1978 FAL	1977 ST	1977 FAL
Wheat										
Barley										
Oats										
Rye										
Rape										
Flax										
Mustard										
Other										

17. What is your usual crop planting policy?

    (1) 1/2 - 1/2 cropping....................

    (2) 1/3 - 2/3 cropping ....

    (3) 1/4 - 3/4 cropping ....

    (4) Continuous Cropping ....

18. On a typical field what is your cropping sequence (including fallow)?

1982	1981	1980	1979

19. How strongly do you agree or disagree with the following statements regarding cropping practices?

Statement	Strongly Agree 1	2	3	4	Strongly Disagree 5.
1. Summerfallowing is the best way to conserve soil moisture.	1	2	3	4	5
2. Summerfallowing is the best method of controlling weeds and crop pests.	1	2	3	4	5
3. Soil moisture is not such a critical problem in continuous cropping as is the general belief.	1	2	3	4	5
4. On the average, continuous cropping gives higher returns per acre compared to summerfallowing.	1	2	3	4	5

	STRONGLY AGREE				STRONGLY DISAGREE
5. Producers who continuously crop their land require more capital investment on machinery.	1	2	3	4	5
6. An important reason to summerfallow is tradition	1	2	3	4	5
7. Summerfallowing reduces operating costs	1	2	3	4	5
8. By summerfallowing, a producer achieves greater income stability.	1	2	3	4	5
9. Continuous cropping makes better use of the land base	1	2	3	4	5
10. Yields on stubble are sufficient to outweigh the cost of increased herbicides, etc. to give higher net farm incomes.	1	2	3	4	5
11. Summerfallow is bad because it increases soil salinity.	1	2	3	4	5
12. Summerfallowing should be discouraged because it contributes to severe wind and water erosion coupled with nitrogen leaching	1	2	3	4	5

	STRONGLY AGREE				STRONGLY DISAGREE
13. Seeding equipment for seeding on stubble is inadequate	1	2	3	4	5
14. Continuous cropping requires increased attention to detail eg, timing of herbicide application	1	2	3	4	5
15. New snow management techniques make continuous cropping feasible	1	2	3	4	5
16. Improvements in blended fertilizers and the practice of banding make continuous cropping more feasible	1	2	3	4	5
17. Improved herbicides on the market today encourage farmers towards continuous cropping	1	2	3	4	5
18. Summerfallowing allows a producer to better plan use of labor and machinery	1	2	3	4	5

20. If the following conditions prevail in a given year my summerfallow acreage would:

	decrease >20% 1	decrease >10% 2	not change 3	increase >10% 4	increase >20% 5
1. Adequate spring moisture	1	2	3	4	5
2. Dry spring	1	2	3	4	5
3. Price of herbicides goes up 50%	1	2	3	4	5
4. Fuel prices go up 50%	1	2	3	4	5
5. Price of fertilizers go up 50%	1	2	3	4	5
6. Land prices go up 50%	1	2	3	4	5
7. Grain and oilseed prices go up 50%	1	2	3	4	5
8. Interest rates go up 50%	1	2	3	4	5
9. No acerage quotas exist	1	2	3	4	5
10. Prices of farm machinery go up 50%	1	2	3	4	5

APPENDIX II: SCHEMATIC DIAGRAM OF SIMULATION
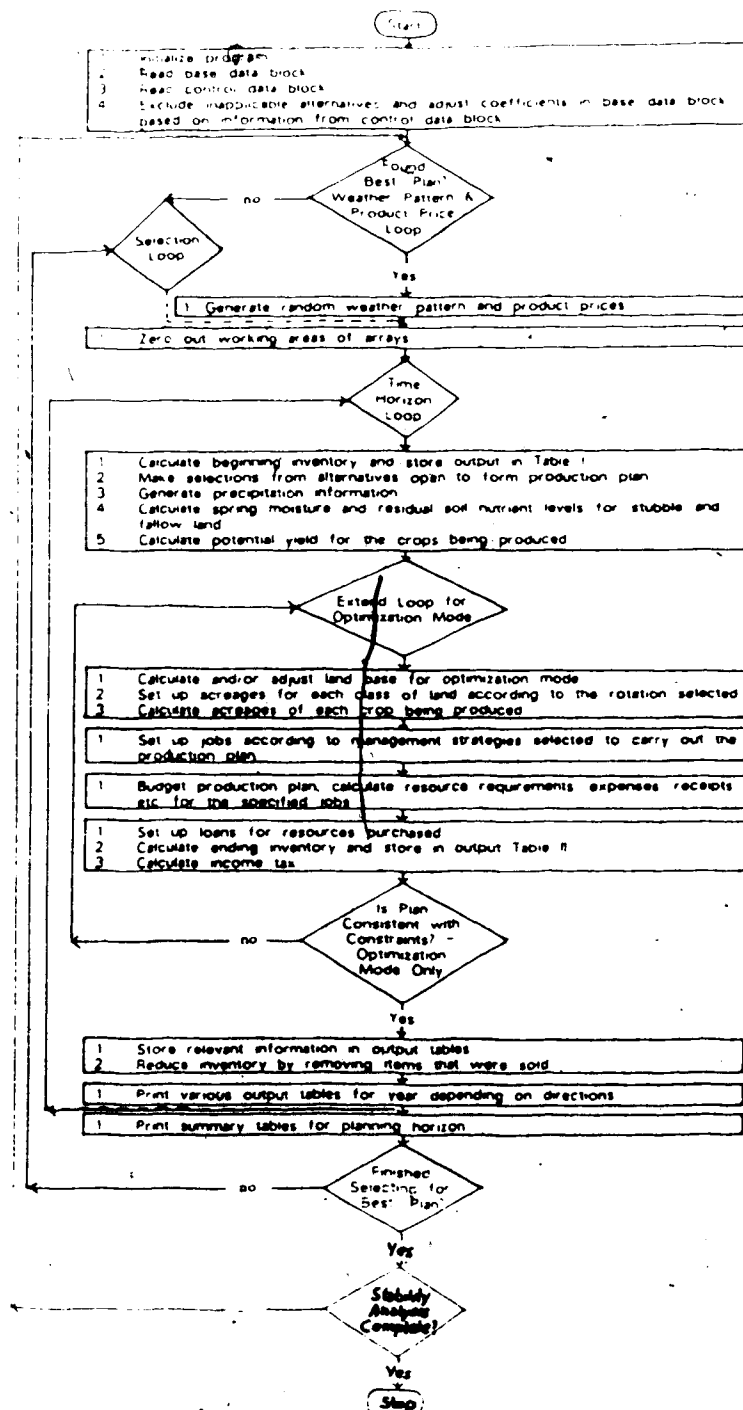
Source R.P Zentner "Prairie Agricultural Farm Simulators (PAFS) Swift Current

Appendix III: Participants Responses to Opinion-Related Statements

	Those With Less Than 67% Cropped	Those With 67% to 89% Cropped	Those With Over 90% Cropped
Number of Farms	7	8	7

Statement

1. Summerfallowing is the best way to conserve soil moisture.

Rating:	Less Than 67%	67% to 89%	Over 90%
5 Strongly Disagree	0	1	3
4 Disagree	1	2	4
3 No strong opinion	2	2	0
2 Agree	3	3	0
1 Strongly agree	1	0	0
0 No response			
Mean Rating:	2.429	3.125	4.428

2. Summerfallowing is the best method of controlling weeds and crop pests.

Rating:	Less Than 67%	67% to 89%	Over 90%
5 Strongly Disagree	0	0	2
4 Disagree	2	1	5
3 No strong opinion	2	4	0
2 Agree	2	3	0
1 Strongly agree	1	0	0
Mean Rating:	2.714	2.75	4.286

3. Soil moisture is not such a critical problem in continuous cropping as is the general belief.

Rating:	Less Than 67%	67% to 89%	Over 90%
5 Strongly Disagree	2	2	0
4 Disagree	1	1	0
3 No strong opinion	2	4	3
2 Agree	2	1	0
1 Strongly agree	0	0	4
Mean Rating:	3.429	3.5	1.857

4. On the average,
continuous cropping
gives higher returns
per acre compared to
summer fallowing.

Rating:				
5	Strongly Disagree	2	0	0
4	Disagree	1	3	0
3	No strong opinion	3	1	0
2	Agree	1	4	3
1	Strongly agree	0	1	4

Mean Rating:	3.571	2.875	1.571

5. Producers who
continuously crop their
land require more
capital investment on
machinery.

Rating:				
5	Strongly Disagree	0	0	2
4	Disagree	1	0	0
3	No strong opinion	2	3	3
2	Agree	3	4	0
1	Strongly agree	0	1	2
0	No response	1		

Mean.Rating:	2.667	2.25	3.0

6. An important reason to
summerfallow is
tradition.

Rating:				
5	Strongly Disagree	3	3	2
4	Disagree	2	2	1
3	No strong opinion	0	0	0
2	Agree	2	3	0
1	Strongly agree	0	0	4

Mean Rating:	3.857	3.625	2.571

7. Summerfallowing reduces
   operating costs.

Rating:	5 Strongly Disagree	2	0	1
	4 Disagree	2	2	1
	3 No strong opinion	2	5	3
	2 Agree	1	1	2
	1 Strongly agree	0	0	0

Mean Rating:	3.714	3.125	3.143

8. By summerfallowing, a
   producer achieves
   greater income
   stability.

Rating:	.5 Strongly Disagree	1	0	3
	4 Disagree	1	1	0
	3 No strong opinion	1	3	·2
	2 Agree	2	3	2
	1 Strongly agree	1	1	0
	0 No response	1		

Mean Rating:	2.833	2.5	3.571

9. Continuous cropping
   makes better use of the
   land base.

Rating:	5 Strongly Disagree	0	0	1
	4 Disagree	0	0	0
	3 No strong opinion	0	0	0
	2 Agree	3	5	0
	1 Strongly agree	4	3	6

Mean Rating:	1.429	1.625	1.429

10. Yields on stubble are
    sufficient to outweigh
    the cost of increased
    herbicides, etc., to
    give higher net farm
    incomes.

Rating:	5 Strongly Disagree	1	2	0
	4 Disagree	1	0	1
	3 No strong opinion	4	4	0
	2 Agree	1	1	1
	1 Strongly agree	0	1	5

Mean Rating:	3.286	3.125	1.571

11. Summerfallow is bad
    because it increases
    soil salinity.

Rating:				
5 Strongly Disagree	2	0	0
4 Disagree	0	0	0
3 No strong opinion	1	1	2
2 Agree	1	3	0
1 Strongly agree	3	4	6

Mean Rating:	2.571	1.625	1.5

12. Summerfallowing should
    be discouraged because
    it contributes to
    severe wind and water
    erosion coupled with
    nitrogen leaching.

Rating:			
5 Strongly Disagree	0	0	0
4 Disagree	1	0	0
3 No strong opinion	2	1	0
2 Agree	1	2	1
1 Strongly agree	3	5	6

Mean Rating:	2.286	1.5	1.143

13. Seeding equipment for
    seedong on stubble is
    inadequate.

Rating:			
5 Strongly Disagree	2	1	1
4 Disagree	1	5	0
3 No strong opinion	1	2	2
2 Agree	1	0	3
1 Strongly agree	1	0	1
0 No response	1		

Mean Rating:	3.333	3.875	2.571

14. Continuous cropping
    requires increased
    attention to detail,
    e.g., timing of
    herbicide application.

Rating:			
5 Strongly Disagree	0	0	1
4 Disagree	1	0	0
3 No strong opinion	1	1	0
2 Agree	1	4	3
1 Strongly agree	4	3	3

Mean Rating:	2.143	1.75	2.0

15. New snow management techniques make continuous cropping feasible.

Rating:				
5	Strongly Disagree	0	1	0
4	Disagree	1	0	0
3	No strong opinion	3	2	4
2	Agree	3	4	1
1	Strongly agree	0	1	2

Mean Rating:	2.714	2.5	2.286

16. Improvements in blended fertilizers and the practice of banding make continuous cropping more feasible.

Rating:				
5	Strongly Disagree	0	0	0
4	Disagree	0	0	0
3	No strong opinion	0	0	0
2	Agree	2	5	2
1	Strongly agree	5	3	5

Mean Rating:	1.571	1.625	1.286

17. Improved herbicides on the market today encourage farmers towards continuous cropping.

Rating:				
5	Strongly Disagree	1	0	0
4	Disagree	0	0	0
3	No strong opinion	0	1	0
2	Agree	4	3	2
1	Strongly agree	2	4	5

Mean Rating:	2.143	1.625	1.286

18. Summerfallowing allows
    a producer to better
    plan use of labour and
    machinery.

Rating:				
5	Strongly Disagree		0	3
4	Disagree	1	2	0
3	No strong opinion	1	1	2
2	Agree	1	2	0
1	Strongly agree	1	3	2

Mean Rating: 3.571   3.25   3.286

If the following conditions prevail in a given year, my
summerfallow acreage would:

Rating: 5 Increase greater than 20%
        4 Increase greater than 10%
        3 Not change
        2 Decrease greater than 10%
        1 Decrease greater than 20%
        0 No response

1. Adequate spring
    moisture.

Rating:				
5	Strongly Disagree	0	0	0
4	Disagree	0	0	0
3	No strong opinion	4	2	1
2	Agree	2	5	1
1	Strongly agree	0	1	1
0	No response	1		4

Mean Rating: 2.667   2.215   2.0

2. Dry spring.

Rating:				
5	Strongly Disagree	0	0	0
4	Disagree	2	5	1
3	No strong opinion	4	2	2
2	Agree	0	1	0
1	Strongly agree	0	0	0
0	No response	1		4

Mean Rating: 3.333   3.5   3.333

3. Price of herbicides
   goes up 50%.

Rating:				
5	Strongly Disagree	0	0	1
4	Disagree	1	2	1
3	No strong opinion	5	·6	1
2	Agree	0	0	0
1	Strongly agree	0	0	0
0	No response	1		4

Mean Rating: 3.167   3.25   4.0

4. Fuel prices go up 50%.

Rating:				
5	Strongly Disagree	0	0	0
4	Disagree	0	0	0
3	No strong opinion	6	6	0
2	Agree	0	1	1
1	Strongly agree	0	1	2
0	No response	1		4

Mean Rating: 3.0   2.625   1.333

5. Price of fertilizers go
   up 50%

Rating:				
5	Strongly Disagree	0	0	1
4	Disagree	2	2	1
3	No strong opinion	4	6	1
2	Agree	0	0	0
1	Strongly agree	0	0	0
0	No response	1		4

Mean Rating: 3.333   3.25   4.0

6. Land prices go up 50%.

Rating:				
5	Strongly Disagree	0	0	0
4	Disagree	0	0	0
3	No strong opinion	6	7	3
2	Agree	0	1	0
1	Strongly agree	0	0	0
0	No response	1		4

Mean Rating: 3.0   2.875   3.0

7. Grain and oilseed
    prices go up 50%

Rating:				
5	Strongly Disagree	0	0	0
4	Disagree	0	0	0
3	No strong opinion	1	0	0
2	Agree	3	3	1
1	Strongly agree	2	5	2
0	No response	1		4

Mean Rating: 1.833 1.375 1.333

8. Interest rates go up
    50%.

Rating:				
5	Strongly Disagree	0	0	0
4	Disagree	0	0	0
3	No strong opinion	6	8	3
2	Agree	0	0	0
1	Strongly agree	0	0	0
0	No response	1		4

Mean Rating: 3.0 3.0 3.0

9. No acreage quotas
    exist.

Rating:				
5	Strongly Disagree	0	0	0
4	Disagree	0	0	1
3	No strong opinion	2	3	1
2	Agree	2	1	0
1	Strongly agree	2	4	1
0	No response	1		4

Mean Rating: 2.0 1.875 2.667

10. Prices of farm
    machinery go up 50%

Rating:				
5	Strongly Disagree	0	0	0
4	Disagree	1	0	0
3	No strong opinion	5	7	2
2	Agree	0	1	0
1	Strongly agree	0	0	1
0	No response	1		4

Mean Rating: 3.167 2.875 2.333