THE UNIVERSITY OF MANITOBA

A MULTIPERIOD LINEAR PROGRAMMING MODEL FOR FARM PLANNING UNDER UNCERTAINTY: A DRYLAND-IRRIGATED SITUATION

BY

WILLIAM ALLAN McBRIDE

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ABSTRACT

A MULTIPERIOD LINEAR PROGRAMMING MODEL
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by

W.A. McBride

Major Advisor - Dr. W.J. Craddock
University of Manitoba

Problems of farm planning and decision making under uncertainty have been investigated in numerous studies of the farm firm, and a variety of models that take some account of uncertainty have been developed. The model used in this study is a contribution to the general class of models that attempt to handle the uncertainty dimension in decision making. The conceptual framework of the model owes much to the work of Boussard. Although the approach here was somewhat different, the basic approach was a variation on Boussard's model.

The major objectives of the study were: (1) to specify a decision model that made some allowance for uncertainty; (2) to assess the economic feasibility of irrigating, in the context of reducing uncertainty, in Southwestern Manitoba; (3) to evaluate the effects of financial reserves in decision making under uncertainty; and (4) to make an assessment of the effects of uncertainty on the efficiency of resource use.

A multiperiod linear programming model with subjective and/or objective considerations of the worst possible outcomes of different alternatives, was used to approximate the problem of farm firm planning under uncertainty. The locale for the study was the Souris River Basin in the southwestern part of Manitoba. A farm firm situation in the area

was specified and this firm constituted the basic resource situation for the applications of the multiperiod model.

The model incorporated both short-term and long-term considerations. The operator was presumed to have a long-run objective of maximizing expected additions to net worth and a short-term objective of being able to afford the unfavourable outcomes that might occur due to chance. This latter objective was incorporated in the model as a worst possible income constraint. A ten-year planning horizon was employed and the model had a total of 189 activities and 86 restraints in each period.

Production alternatives in the model included such crops as wheat, oats, barley, rapeseed and forage - both dryland and irrigated and both insured and uninsured. Yields for the irrigated crop production alternatives were developed from analysis of the long-term relationships between yield and moisture deficiency for some crops grown in the area.

To evaluate the model for purposes of making some allowance for uncertainty, solutions were prepared for what were called deterministic and stochastic cases. In the deterministic use, only the expected value criterion was employed. In the stochastic case, the worst possible income criterion was used as an additional decision criterion. In the latter case, the worst possible income constraint was varied parametrically from a lower level at which it was not an effective constraint, to an upper level beyond which an optimal plan was no longer feasible.

Taking differences in first period plans as most important, there were substantial differences between the deterministic and the stochastic optimal plans for the same resource situation. In the first case, solutions emphasized oilseed crops, without crop insurance and with heavy applications

of fertilizer. In the latter case, the solutions placed more emphasis on wheat production, took advantage of crop insurance and specified a lower level of fertilizer use.

The irrigation system considered in the study was a capital-intensive centre-pivot system. The analysis indicated that, while this alternative would improve the expected gross margin of the firm, it would not be profitable to acquire it for the cropping alternatives that were considered in this study. At the same time, the opportunity to irrigate in years in which dryland yields were low because of moisture deficiency was found to be quite profitable. Irrigation would clearly reduce the uncertainty associated with dryland farming and would improve the worst possible income position in any one year. However, the average benefits from irrigating were not enough to justify the average costs of owning the irrigation system. Higher value crops and/or an irrigation system with a lower capital requirement would have been necessary to make irrigation competitive with dryland production.

Financial reserves were hypothesized as an important factor affecting the ability and willingness of farmers to afford risk and to adopt plans with more uncertain outcomes. The applications of the model with different levels of reserves--in the form of cash reserves and in the form of borrowable reserves--supported the hypothesis. The optimal plans incorporated more risky alternatives when reserves were ample than when they were limited.

In the formal sense, the model used in the study can accommodate farm-specific information concerning alternatives, assets, objectives and expectations. At the same time, it has obvious limitations. As examples, the model presented does not formally allow for diversification as a means

of reducing uncertainty and the worst possible estimates were not statistically based. For practical application to actual farm situations, the suitability of the model would be improved by having fewer alternatives and a shorter planning horizon with consequent reduction in data requirements.

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CHAPTER 1

INTRODUCTION

THE PROBLEM AND THE OBJECTIVES

The basic problem that concerned this study was that of improving farm incomes and expanding economic opportunities in the Souris River valley in southwestern Manitoba. This is an area in which soil moisture is usually a limiting factor in crop production. A remedy for the moisture deficiency problem lies in the supplies of ground and surface water in the area and potentially available for farm use from ground wells and/or from a proposed set of storage reservoirs on the tributaries of the Souris.[1] This study contributes background material for the economic evaluation of both public and private participation in developing water supplies for irrigation.

The direct problem for this study was that of decision making by an individual firm and the overall objective was to investigate the effects of uncertainty on farm firm planning, decision making, and the efficiency of resource use. Specifically the study was initiated to evaluate the economic feasibility of changing from dryland farming to a combination of dryland and irrigation farming, taking account of the uncertainties of results in both cases.

Irrigation has the potential to reduce the crop yield uncertainties of dryland farming and to improve average yields. At the same time,

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[1] At the time of this study, public investment had not been committed to developing the water supplies and private investments in irrigation facilities were not significant.

decisions concerning irrigating have to be evaluated in the context of the complete decision environment and in terms of the overall costs and benefits. There are, for example, other ways of reducing or accommodating dryland yield uncertainties--principally through crop insurance and financial reserves; other ways of improving expected dryland yields--principally through improved fertility and management; and other sources of uncertainty which are not substantially reduced by irrigating--principally price. This study specifically considered these factors in evaluating irrigation and explicitly recognized uncertainty with respect to yield, price and irrigation water requirements.

As shown in a later section, risk and uncertainty are economic facts of life in the decision environment of farms in the Souris Basin. They must be taken into account when decisions are made; many farm managers make allowances for them as a matter of course. Nevertheless, the problems of how best to allow for uncertain outcomes and how to incorporate lack of knowledge about different outcomes into decision criteria are difficult both in theory and in practice.[2] An instrumental objective of this study was to develop decision models for the farm firm that would approximate the real-life decisions of farmers in situations similar to those identified in this study.

This study is a successor to many other applied studies of the problems of decision making under uncertainty. Some of these studies that were concerned with farm situations are discussed in the third chapter. As for studies on the economics of irrigating in the Souris Basin, irrigation and dryland

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[2]For a sampling of theoretical and applied literature in this area, see G. J. Hahn, A Categorized Bibliography on Decision and Risk Analysis (Schenectady: General Electric Co., Report No. 69-C-189, 1969).

farming had been analyzed in studies by Finn[3] and by Singh.[4] Besides these studies on the Souris, irrigation farming in the Pembina Triangle area of Manitoba has been evaluated in earlier studies by Boyko[5] and by Iga.[6] The difference between this study and the earlier ones is that it takes account of uncertainty in the context of a multidimensional planning horizon, when comparing dryland and irrigation farming. The study by Boyko took specific account of the time horizon but not of uncertainty; that by Iga took specific account of uncertainty but not of time.[7] There remained the possibility that decisions and the economic feasibility of irrigating would be substantially affected by specific consideration of both time and uncertainty.

This study took advantage of existing economic theory in developing the decision models and in testing hypotheses. The models themselves relied in part on the contributions of McInerney, of Hazell and of Boussard.[8] They were slightly different from those of previous studies in their representation of the decision process. The main difference lay in the attempt to

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[3] G. J. Finn, "An Economic Feasibility Study of Irrigating from Groundwater in South Western Manitoba" (Unpublished Master's Thesis, University of Manitoba, 1971).

[4] R. H. Singh, "An Economic Analysis of Irrigation in the Souris River Basin in Manitoba" (Unpublished Master's Thesis, University of Manitoba, 1972).

[5] E. S. Boyko, "A Multi-Period Analysis of Capital Accumulation and Financing of Beginning Irrigation Farms in the Pembina River Basin" (Unpublished Master's Thesis, University of Manitoba, 1969).

[6] M. Iga, "Economic Evaluation of On-Farm Irrigation in the Morden-Winkler Area of Southern Manitoba" (Unpublished Ph.D. Dissertation, University of Manitoba, 1970).

[7] The studies by Finn and by Singh did not specifically consider uncertainty or the time dimension.

[8] Their contributions are discussed in Chapter 3 and are referenced in the periodicals section of the bibliography of this study.

incorporate both long-run and short-run considerations into a linear programming representation of a game theoretic decision rule.

Variability in Production and Returns in the Souris Basin[9]

The yield data for Crop District Number 1 shown in Table 1 provide some evidence of the degree of production uncertainty in the Souris Basin. The long-term coefficients of variations in yields for the four crops wheat, oats, barley and flax, range from 37 percent to 53 percent and as such indicate a fairly high degree of instability. Also when yields in District 1 were compared with those in the province as a whole, the District yields were lower and more variable.[10]

Table 1

Variability in Yields of Wheat, Oats, Barley and Flax in Crop District Number 1, 1932-1970[a]

Crop	Mean Yield[b]	Coeff. of Variation
	bushels per acre	percent
Wheat	12.07	37
Oats	18.74	53
Barley	15.09	47
Flax	6.30	44

[a]Yields in Crop District Number 1 were used here as a measure of yields in the Souris Basin. Most of the Basin in Manitoba is within District Number 1. See map on p. 5.

[b]Mean yields were computed from time series data with linear trends removed.

Source:
Calculated from data prepared for W. J. Craddock, Interregional Competition in Canadian Cereal Production, Special Study No. 12, Economic Council of Canada (Ottawa: Queen's Printer, 1970).

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[9]The Souris River, Crop District Number 1 and the specific area that concerned this study are identified on the map on page 5. For a general description of the area see Finn, p. 15 and Singh, pp. 3-4.

[10]Based on trend-free yields of wheat, oats, barley, flax and rye for the period 1952-1971.

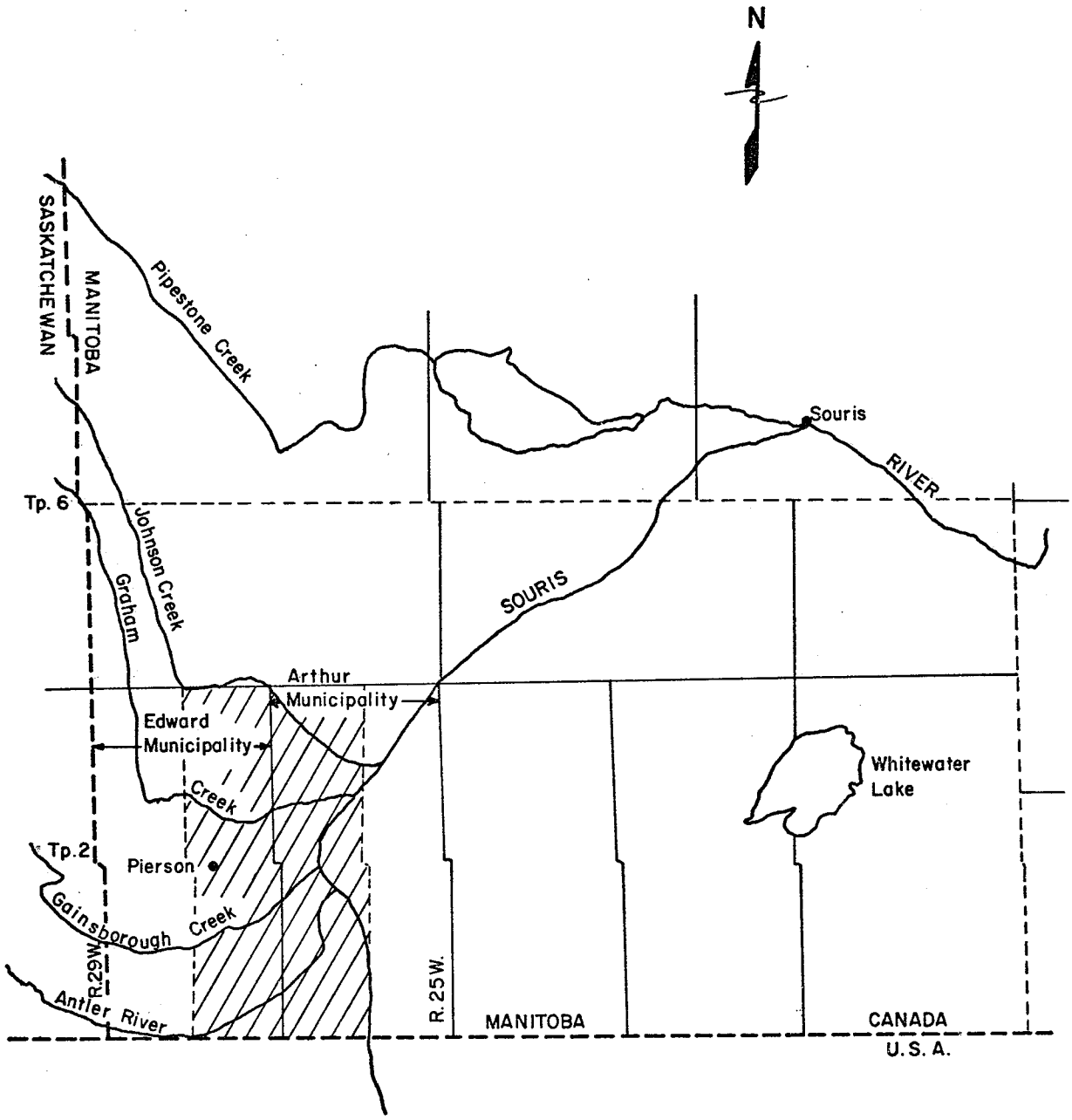

Figure I Map of Portion of Souris River and Tributaries in South-Western Manitoba, Boundaries of Crop District Number I and Area Used for Dryland Yield Estimation.

------ Boundary of Crop District Number I

Area Used for Dryland Yield Estimation

Variability in yields, in prices and in other facets of the farm decision environment have their ultimate effects on financial variables such as cash flow, cash income and net farm income. An indication of the degree of variation in the net income of a typical farm business in the Souris Basin was obtained from the time series of net incomes of all Manitoba farmers.[11] For the period 1960-1971, the average net farm income per year was 132 million dollars with a 26 percent coefficient of variation. For five years in which net incomes declined from the previous year, the average decrease was 30 percent; for six years in which it increased, the average increase was 150 percent. Similar evidence of variability in incomes could have been obtained from the records of individual farm businesses in the Souris Basin. The degree of variability would of course also vary from farm to farm.

Variation in net incomes to the degree just noted was enough to justify serious consideration of the different means of stabilizing them.[12] Among the means of stabilization are all-risk crop insurance, diversification, irrigation and the proposed and subsequently withdrawn Grain Stabilization Plan.[13] These different schemes are evidence that stability of income is one of the criteria that farmers use in evaluating alternatives. Whether it is an important and worthwhile criterion depends finally on the answers to two questions: (1) What would be the costs and benefits of stability of

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[11] See Appendix Table B.1.

[12] This was aside from the issue and the means of increasing net farm income.

[13] O. E.Lang, Minister Responsible for the Canadian Wheat Board, "Proposals for a Production and Grain Receipts Policy for the Western Grains Industry" (Mimeographed) 1970. (A revised plan was subsequently proposed and adopted in 1976).

earnings? (2) Who would pay the costs and who would receive the benefits? This study was concerned, in part, with estimating the benefits.

Uncertainty and Economic Efficiency

It is because of uncertainty that there is a need for the managerial role in agricultural production. Management is rewarded as a factor of production because the future is uncertain and because there are differences of opinion about what the future holds. The reward that it receives is in part a reward for making risky choices successfully.

Another side of risk, however, is its relationship to economic efficiency. If the return to entrepreneurship is somehow a private benefit of risk, misallocation of resources is both a private and a social cost of risk. As noted by Heady, there are two kinds of inefficiency which grow out of uncertainty:

> "(1) Precautions which are taken to meet uncertainty almost always necessitate a sacrifice; they either result in a less-than-maximum product from given resources or, conversely, do not allow a minimum cost for a given output. (2) Both the individual farmer and the consuming society sacrifice when production is geared to inaccurate expectations."[14]

If the precautions to meet uncertainty tend to restrict output below what it would be with perfect information, it could be expected that an increase in output would accompany a decrease in uncertainty. Whether economic, as well as technical efficiency, would be improved by such an adjustment was a question that concerned this study.

STATEMENT OF HYPOTHESES

The major objectives of the study are expressed in the following

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[14] E. O. Heady, Economics of Agricultural Production and Resource Use (Englewood Cliffs: Prentice-Hall Inc., 1952), p. 530.