AN ECONOMIC FEASIBILITY STUDY OF IRRIGATING FROM GROUNDWATER IN SOUTH WESTERN MANITOBA

A Thesis

Presented to

the Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Gerald Joseph Finn

October 1971

ABSTRACT

The prime objective of this study is to determine the economic feasibility of sprinkler irrigation in the Melita area. This has been done by constructing a farm model which is representative of the project area. Using this model as a base, several new enterprises were added. These additions include the potential for a livestock enterprise, specialty crop enterprises, and irrigation.

The major methods of irrigating are reviewed and one of these, sprinkler irrigation is adopted for the study.

The linear programming solutions suggest that the farm that integrates dryland and irrigated cropping along with some livestock, is the most successful financially. Livestock enables the farmer to more fully utilize his available labor.

Although the cost of irrigation is high relative to the cost of operating similar acreages under dryland conditions, with good management the returns are adequate to cover costs. Return to management and investment equity in machinery, equipment, and buildings, computed for each plan using irrigation is favorable.

ACKNOWLEDGMENTS

A sincere acknowledgement is given to Dr. W.J. Craddock who served as major adviser to me throughout this project. His helpful comments and suggestions played not a small part in my research.

Acknowledgement is also given to Dr. R.E. Capel and Dr. G. Laliberte who acted as committee members and made many helpful suggestions on an advanced draft of the thesis.

Several of my colleagues offered valuable assistance during my sojurn in the Department. While too numerous to mention, acknowledgement is warranted.

Finally, I must acknowledge my wife's fortitude in typing the major share of the many drafts and my children's forbearance in my absence during the past many months.

TABLE OF CONTENTS

LIST OF TABLES

List of Tables (Continued)

LIST OF FIGURES

Chapter 1

I. INTRODUCTION

Polarized about Melita, the South West Manitoba Development Commission was formed in 1962 with it's main purpose being "to organize and promote more intensive economical development of the area".[1] To achieve this aim it was recognized that agricultural production would have to be intensified. The development of a dependable supply of water was considered essential. The Commission was hopeful of utilizing ground water for irrigation development. In seeking this end, a ground water availability study was carried out by the Water Control and Conservation Branch of the Manitoba Government under an Agricultural Rehabilitation Development Act Agreement.

The purpose of the ground water study was to make an appraisal of the ground water resources in the Melita area and the possibility of using this ground water for irrigation.

The study found that from the standpoint of utilizing ground water for irrigation, the outwash deltas, particularly sand and gravel, constituted the most significant aquifers[2] in

---

[1]Manitoba Government, Department of Mines and Natural Resources, Water Control and Conservation Branch, Planning Division, <u>Ground Water Availability Studies</u>, Report No.1, p. 1.

[2]An aquifer is defined by the U.S. Geological Survey as a rock formation or stratum that will yield water in sufficient quantity to be of consequence as a source of supply.

the area. The Broomhill outwash delta aquifer, directly north of Melita, within the southwest portion of the Souris River basin, underlies an area of 25 square miles which is suitable for irrigation (2). The water quality from outwash delta sand and gravel in Southwestern Manitoba is good to excellent for irrigation.[3]

The Research Branch of the Canada Department of Agriculture studied three separate locations around Melita in 1963 for soil suitability for irrigation studies. In two of the areas studied, the soils were determined to be sandy loams to loamy sands overlying coarse sands and gravel at about two to three feet. It was felt that drainage would be adequate. Low water storage capacity and high water intake rates would mean fairly frequent irrigations, but it was concluded that irrigation should be feasible. In the third area, the soils were superior to the other two study areas because of the deeper location of the coarse sands and gravel. Again, irrigation was considered realistic with fewer irrigations being felt necessary in this soil.

Further investigations indicated that it was technically possible to effectively irrigate such crops as alfalfa, potatoes, and corn by sprinkler irrigation using ground water from dugouts. The Melita area was considered to have distinct possibilities for irrigated hay and pasture production.

---

[3]Manitoba Government, op. cit., p. 1.

In the past few years, much experimental irrigation work has been carried out in the Melita area. To this point, field peas, corn, potatoes, and sunflowers are some of the crops that have been grown successfully on an experimental basis (20).

The feasibility of developing an irrigation project in this area would be of interest to the local farmers who are presently operating under dryland conditions. If it is economical for individual farmers to tap the ground water, and, if it is available on a dependable basis, precipitation would no longer continue to be a limiting factor in the production process. The introduction of irrigation would necessitate changes in farm organization and would likely take several seasons until the most efficient methods were attained and fully integrated.

II. OBJECTIVES OF THE STUDY

The overall objective of this study is to determine the economic feasibility of sprinkler irrigation in the Melita area. This has been done by constructing a farm model which is representative of the project area. Using this model as a base, several new enterprises were added. These additions include the potential for a livestock enterprise, cash crop enterprises, and irrigation.

The initial objective of this study is to present a descriptive review of the main methods of irrigating. A more intensive look is then taken of one of these methods --

sprinkler irrigation. This review presents the suitability of these methods under different geographical conditions. Cost comparisons of several methods of irrigating are then given.

The second objective of the study is to determine the economic feasibility for the representative farm in irrigating from the Broomhill Aquifer. The study will then examine the impact on income and enterprise mix as a result of alternative conditions for certain resources.

III. SCOPE OF THE STUDY

A single farm, representative of the Melita area, was developed and used for the study. The farm is of average size, has average levels of resources and reflects the dryland structure and organization of the area. The basic data for the farm are similar to conditions existing in the study area and where this has not been possible, the data are adapted from similar areas.

The results from this study could assist in the development of the Melita area. In the event that irrigation is economically feasible, the study could be used as a guide for potential irrigation farmers. The analysis of the farm plans attempts to indicate some factors which should be taken into account while planning irrigation farming. These factors could aid the farmer in realizing full irrigation potential more quickly. However, it must be remembered that the results of this study should be considered only as guides. They were derived by using a particular set of assumptions regarding prices, costs and productivity. It cannot be determined whether or not, or for how long a period of time, an individual farmer would be faced with this particular set of assumed economic and technological conditions.

Chapter 2

IRRIGATION REVIEW

I. REASONS FOR IRRIGATING

Two main reasons for irrigating can be identified. The possibility of greater direct net returns from irrigated crops is of primary importance. There are several cash crops such as sugar beets, corn, and potatoes that cannot be grown in the study area due to the lack of adequate precipitation and an improper temporal distribution of precipitation. However, with the advent of irrigation, it could be quite profitable to grow some of these crops. Feed grains and forages have been successfully irrigated in areas similar to Southwestern Manitoba. This usually has led to a livestock enterprise which utilizes these crops.

The second major reason for irrigating is the income stabilizing effect. Irrigation is a means of satisfying crop water needs and permits the farmer to apply water at the most critical times. In this way, irrigation is really like insurance since it allows farmers to predict incomes more accurately.

II. METHODS OF IRRIGATING

There are three general methods of irrigating. The first, subirrigation, is still considered to be in the experimental stages. It might be defined as regulation of the elevation of the ground water table by artificially adding water underground. Subirrigation is drainage in reverse. With drainage, the excess water flows through the soil toward and into the drains. Such a drainage system lowers the water table so that the development of the root system and the growth of crops is not limited because of lack of air. With subirrigation, water is diverted into drains and then infiltrates out into the soil. In this way, the water table is kept at a proper height so that crops can derive their water needs from it. This requires knowledge of the varying water needs and rooting habits of the different crops at all stages of development.

For subirrigation to be effective, the soil must be smooth and nearly level and there must be either a natural or regulated water table which can be maintained at some predetermined subsurface elevation. Other major restrictions of this method are that where annual precipitation is low, at least one annual surface irrigation may be necessary to leach out salts. Surface irrigation may also be necessary to get a crop germinated. During the growing season, the water table must be controlled within limits determined by the crop growth cycle.

An advantage of this method is that the labor requirements are low for a well-designed system. Furthermore, evaporative loss of water from the land surface is minimal.

Some of the more extensive subirrigated systems are found in the Netherlands. The climate, topography and soils of this area necessitate that drainage facilities be utilized for sustained crop production.

Subirrigation methods have been used successfully in several areas of the United States. Florida has two extensive areas where conditions are suitable for subirrigation: the Everglades and the Flatwoods of the Coastal Plain. Until recent years, these lands were either too wet or too dry for good crop production. Water table control through subirrigation and drainage has increased production several hundred percent in these two areas.

Other areas of note where subirrigation is used, include California, Idaho, Colorado, Utah, and Wyoming. In each case, vast tracts of land that were previously unsuitable for crop production are now being subirrigated profitably. Project areas that use subirrigation tend to be extremely large, for example 160,000 acres in the Sacramento-San Joaquin Delta of California and 135,000 acres in the San Luis Valley of Colorado. This magnitude is required in order to insure that neither drainage nor return flows in the area cause the water table to fluctuate beyond desirable limits.

In this study, the total area under consideration is relatively small in comparison to those subirrigated areas that have been mentioned. Although the water table could easily be managed, as this method requires, it is felt that other methods of irrigating would be more appropriate for a small-scale project. These alternatives will now be discussed.

Another method of irrigation is surface irrigation. These systems may be grouped into two broad classifications, complete flooding of the soil surface and partial flooding or furrow method. In complete flooding, the entire land surface in the area being irrigated is covered with water. Water is conveyed to the area in a supply ditch or pipeline, and is distributed over the soil surface in a sheet.

In the partial flooding or furrow method, the entire irrigated area is only partially flooded. Closely spaced furrows (small ditches) contain and distribute the water which moves both laterally and downward from the furrow to moisten the plant root zone.

In contrast to subirrigation, this method can be used on nearly all irrigable soils and most row crops. The system can be tailored to accomodate a wide range of stream sizes and still maintain a high water application efficiency. This method is used much more extensively than the first.

Surface irrigation systems are usually inexpensive to operate when compared with other methods of application because of low power requirements. Water is usually applied directly to the farmland by gravity flow from the irrigation project's canals and laterals. Where water is pumped from wells, rivers, storage reservoirs, or other sources of supply, only enough power is needed to raise the water surface slightly above the land which is to be irrigated. Labor requirements and costs may be more or less than with other methods of irrigation depending on the systems being compared, the manner in which they are operated, the availability of low cost labor, and whether or not automatic controls are used. For example, in South Dakota a gravity ditch system with siphon tubes was estimated to have fixed annual costs associated with irrigation of $23.91 per acre. Another surface system, the gated pipe, in the same area and calculated on the same basis, was estimated to have an annual fixed cost of $42.95 (1,p.4). These costs are representative of what would be found in Manitoba. Table 2-1 contains cost estimates and comparisons of several irrigation systems for Manitoba.

The gated pipe system requires less labor for field operations, whereas the gravity ditch system is estimated to be almost free from costs of repairs. Most surface systems are characterized by low repair costs. The potential economic loss due to failure of the system or to shut down for repairs is small.

Investment costs for surface systems will vary directly with the natural topography of the land. If extensive leveling is necessary, costs may be exorbitant. Special equipment will be required and less extensive leveling will need to be repeated every few years. It is estimated that for a gravity system, the typical cost of new leveling and shaping will be $12,000 per quarter section (1, p.2). This cost can be expected to prevail in the research area.

Another major limitation of surface systems is their inefficient use of water on sandy soils. Since water enters these soils so rapidly, excessively deep percolation causes the system to be inefficient. The dominant soil type covering the Broomhill aquifer is of a sandy nature and hence, it would

Table 2-1

ESTIMATED[1] COST COMPARISONS OF SELECTED IRRIGATION SYSTEMS IN SOUTHWEST MANITOBA (1970 Prices)

Cost item	Surface systems gravity ditch	Surface systems gated pipe	Sprinkler systems towline	Sprinkler systems self propelled
Fixed (per 160 acres) $				
well	3600	3600	3600	3600
motor and pump	1403	1492	3842	4103
sprinkler system			4869	15898
land leveling	12000	12000		
pipe and misc.	168	4438	3145	4022
Total new investment	17171	21530	15456	27623
Acres irrigated	156	156	152	138
Investment per acre	110	138	102	200
Variable (per acre) $				
power	1.95	1.55	3.25	3.85
lubricants, repairs, and maintenance	.84	.63	.45	.27
Labor (hours per acre)				
variable[2]	2.17	.90	.96	.09
fixed[3]	.72	.27	.23	.27

1/ Estimates were adapted from the following sources:

W.G. Aanderud, R. Sorenson, and S.D. Black, Irrigation Costs and Returns, Extension Circular 680, Cooperative Extension Service, South Dakota State University (Brookings, 1970).

Baker Manufacturing Ltd., Winnipeg, Manitoba.

W. McMartin, and R.O. Bergan, Irrigation Practices and Costs in North Dakota, Bulletin 474, Agricultural Experiment Station (Fargo, 1968).

2/ Includes only the labor used in applying water.

3/ Includes getting the system ready in the spring, putting it away in the fall, ditching, leveling, cleaning ditches, etc. For the sprinkler systems this would only be variable labor for any one year until the first irrigation was started.

probably be inefficient for surface irrigation.

The third major method of irrigating is sprinkler irrigation. Sprinkler systems may be grouped into three general classes according to portability: (i) portable, (ii) semi-portable, and (iii) stationary. The portable and semi-portable systems are most commonly used in agriculture. The stationary system is often used for golf courses and parks.

These systems are adaptable to most soil and topographic conditions. This type of irrigation can be used on an undulating surface, whereas, a gravity or surface system cannot. As well, a sprinkler system can apply water to soils at rates equal to, greater than, or less than the rate at which water enters the soil. This allows them to be designed for light or heavy soils.

The fixed costs for the semi-portable systems are generally higher than for the manual (portable) systems. For example, in Manitoba, based on a system capable of servicing a quarter section, the new investment per acre was estimated to be $200 for an automatic self propelled model and $102 for the manual towline (see Table 2-1).

The variable costs excluding labor, were generally about 11 percent higher per acre for the automatic system. The labor required for each type indicated that the towline required about 50-70 percent more labor per acre for any given crop.

Similar cost comparison studies in several project areas in North America, corroborate the above observations

(5, 13). Generally, the completely automatic system is about 50 percent more expensive to purchase and 10-15 percent cheaper to operate. However, the automatic is more economical in terms of labor as it requires about one-third as much labor as does the towline or manual sprinkler systems.

A limited water supply gives sprinkler irrigation a slight advantage over gravity irrigation. Sprinklers are more efficient applicators of water than are gravity systems. It is possible to "stretch" water over about 10 to 15 percent more acres by applying it through sprinklers.

In the study area, the soils are very sandy and would tend to favour a sprinkler system. For this reason, the two sprinkler types mentioned, the self-propelled or centre-pivot and the towline are considered as possible methods of irrigating. This will contrast a high capital and low labor cost alternative against one with a low capital and high labor cost.

Chapter 3

MODEL BUILDING

In this chapter, a description of the farm that was used to represent an average farm in the study area will be given. The manner in which the empirical model was specified will also be described.

I. METHODOLOGY

Linear programming, a procedure by which a linear objective function can be optimized subject to linear inequality or equality constraints, is the analytical technique adopted in this study.[1] The general linear programming problem may be stated in mathematical notation as:

$$\text{Optimize} \quad Z = \sum_{j=1}^{n} c_j X_j$$

$$\text{Subject to} \quad \sum_{j=1}^{n} a_{ij} X_j \ (\leq, =, \geq) \ b_i \quad (i = 1, \ldots, m)$$

$$\text{and} \quad X_j \geq 0 \quad (j = 1, \ldots, n).$$

The objective to be optimized, Z, is a linear function of the levels of activities[2], X_j, each with a corresponding

[1]Optimum, as used in this study, refers to an allocation of resources amongst alternative enterprises, such that income cannot be further increased by an additional reorganization in resource use.

[2]An activity is defined as a method of converting resources into a product. A particular activity is unique in that it uses resources in specified proportions.

value c_j. The optimization takes place subject to restraint levels b_i, which are "required" by activities X_j in the amounts of a_{ij} per unit.

For the purposes of this study, the objective to be maximized using the linear programming model, is net farm income. The productive activities consist of alternative types of dryland and irrigated crops and a feeder cattle possibility. Activities are also used to enable the purchase of scarce resources. The choices amongst these alternatives are limited by the available resources and markets, and by subjective restrictions of management, all of which are expressed in the form of quantitative restraints.

II. STUDY AREA DESCRIPTION

The study area is in the Souris River Basin directly north of Melita in the South West corner of Manitoba. The area rests in the rural municipalities of Albert and Arthur in census division four.

Major soils in this region include Almasippi, Souris, Bede, and sand dunes. The soils are highly susceptible to wind erosion and subsequently should be protected by vegetative cover at all times.

A moderately low water holding capacity renders these soils droughty. These sandy-textured soils occur on a gently sloping topography and are generally well suited for forage crop production because of the high water table and the limy nature of the soil. There are indications that these soils may be potassium deficient for horticultural crops.

The Souris River Basin is in general characterized by a high percentage of land with soil combinations suitable for irrigation (3). Sources of water are plentiful in this Basin. However, groundwater is the only source readily available north of Melita and is the only concern in this research.

The average temperature from May to August in the project area is 60.8 degrees Fahrenheit. Melita has an average of 107 frost-free days per year. Precipitation is 19.48 inches per year with 11.45 inches during the growing season from May to August inclusive.

III. PRESENT AGRICULTURE IN THE AREA

In 1966, there were 1775 farms in census division four with annual sales of agricultural products valued at $2500 or more. Wheat farms constituted 44 percent (776 farms) and small grains (exclusive of wheat) another 36 percent (636 farms) of this total. There have been small amounts of both mixed and livestock farming in the region. Table 3-1 summarizes the farm types that prevailed in the census division in 1966.

Present Organization of the Farms

Land use. The land in the project area is sandy and as a result is extremely susceptible to wind erosion. About 25 percent of the total improved area is in summerfallow