ECONOMICS OF NATURAL AIR DRYING ON MANITOBA GRAIN FARMS

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Research Bulletin No. 90-2

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October 1990

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FOREWORD

This project was undertaken with partial funding from Agriculture Canada through the Agri-Food Agreement. The University of Manitoba through the Department of Agricultural Economics also funded a portion of the research.

Although the project addresses a relatively simple problem, "Does natural air drying investment pay in southern Manitoba? ", the analysis became a very large undertaking. Our approach was to use a Manitoba Agriculture software program, "Grain Drying System Design" in order to examine the use of different equipment combinations under different use conditions. We then developed our own software application to translate these technical characteristics into economic criteria using benefit/cost methodology. As the number of different combinations of events which could have been analysed within this project exceeds 25,000, we had to be selective in what was analysed and what was reported.

Many people contributed to our analysis, but W.E. Muir, Professor of Agricultural Engineering at the University of Manitoba, D.N. Huminicki and O.H. Friesen both agricultural engineers with Manitoba Agriculture, Don Taylor and Harry Harms of Westeel, and R.F. Boucher of Behlen Industries Ltd., were particularly helpful. We acknowledge their assistance and support.

It should be noted that the analysis uses data, product specifications and computer programs provided by several sources. We have applied these inputs as carefully and as objectively as the time, resources, and capabilities of the project permitted. Consequently, we can vouch for the authenticity of the results only up to the point of control over the data resting in our hands. We believe the results are dependable within the framework which was developed but we cannot be held responsible for errors occurring beyond our control.

In order to more closely simulate actual conditions, it was necessary to use company specific equipment in both computer programs. Despite its usage, the authors wish to emphasize the analyses were not intended to be interpreted as an evaluation of individual company products but rather types and sizes of bins and fans. The multiplicity of drying conditions could clearly yield alternative results under different situations.

The project went through three distinct phases. The first involved conceptualizing the problem and developing an analytical framework which was done by Dr. R.M.A. Loyns and Mr. D. Frank. The second phase involved identifying relevant scenarios and conducting the analysis, which was undertaken by Ms. L. Hope and Mr. Frank, with Mr. Frank writing the software package to transform the technical data to economic results. The final stage of assembling and drafting the final report, was undertaken by Ms. Hope and assisted by Dr. Loyns.

SUMMARY

Harvesting under adverse weather conditions frequently results in a lower quality and quantity of grain production. Generally, the longer the grain is left on the field, the higher the probability of damage from adverse weather. Moisture in the form of rainfall and heavy dew may lower the quality of grain through reductions in protein content, colour change, growth of mould, sprouting, as well as reduce the test weight of the grain. Tough or damp grain may also lead to spoilage or contribute to insect damage in storage. Consequently, the grain when delivered into the marketing system, is valued (and priced) lower than grain at acceptable moisture levels (straight grades). Grain combined at higher temperatures may produce similar results in storage.

Installation of grain drying and aeration systems allow for earlier harvesting, cooling and drying of grain thus reducing the risk of spoilage during storage. While grain drying and aeration systems have obvious benefits, they also involve significant costs.

The objective of this study is to investigate the financial profitability of investing in a natural air drying system. The specific objective of the study was to determine the financial viability of installing a natural air drying (NAD) system for three grains: wheat, barley and canola at three locations: Winnipeg, Brandon and Dauphin. A secondary contribution is the development of a farm management tool that will aid farmers in their capital budgeting decisions. A computer software package was developed which allows farmers, extension personnel or bin manufacturers, distributors and retailers to demonstrate the costs and benefits of NAD under particular circumstances outside of the analysis undertaken.

The methodology adopted is that of a traditional benefit/cost approach used to determine the profitability of NAD. The expected net returns over the life of the system were

estimated using two computer programs. The costs involved in drying the grain in the NAD bin were simulated by a computer program, "Grain Drying System Design" developed by Manitoba Agriculture. Using a computer spreadsheet program, the drying costs estimated by the MDA program along with other technical parameters specifying harvest conditions were entered into the cost/benefit tableau (NADCBA) developed by the authors to estimate the costs and benefits of the system. Based on the annual net returns earned over the economic life of the system and the initial capital expenditure on the NAD system, the profitability of the NAD system was assessed on the basis of three evaluation criteria, net present value, internal rate of return and benefit/cost ratio.

The number of parameters specifying the NAD system and conditions of harvest presented a vast number of combinations that could be analyzed. In order to provide representative results and to give as complete a picture as possible of the economics of air drying in Manitoba, the authors adopted a case study approach to the problem. Specific combinations of bins and fans were selected to represent the range of different production practices in the province. Variations in parameters such as grain, location, bin size and configuration, fan type and model, harvest date, initial moisture, place of final moisture measurement, price of grain, price of electricity, humidistat control and type of flooring were tested to determine the profitability of NAD under different conditions. Finally, the sensitivity of the evaluation criteria to changes in the values assigned to the technical parameter were tested for several scenarios, using sensitivity analysis. The results of 88 scenarios analyzed and sensitivity analysis of 18 technical parameters used in two of the scenarios are listed.

Based on the values of the technical parameters used in the study and the various combinations of conditions imposed, the analysis indicated that the base NAD system, (consisting of a 10 horsepower centrifugal fan and a 3,000 bushel bin), showed very favourable positive returns when barley/wheat/canola, barley/canola or wheat/canola combinations were dried. A NPV of $4,420 was estimated when one batch each of barley, wheat and canola were dried. Given the level of capital investment in the base NAD system, benefits generated drying barley/wheat or barley or wheat individually were not great enough to cover operating expenses and the initial capital investment. Similarily with smaller NAD systems comprising 1,200 and 1,500 bins and 1.5 hp axial fans, the benefits generated were not large enough to cover operating expenses and initial capital investments. Conversely, the analyses indicated that large NAD systems consisting of 7,500 and 10,000 bushel bins were extremely profitable, earning as much as $4.00 in present value terms per dollar invested. A NPV of $37,000 was estimated for a NAD system drying barley/wheat/canola in a 10,000 bushel bin to the average bin moisture content specified by the farm operator.

Several generalizations are made concerning the profitability of NAD systems and recommendations for further research are made. In general, NAD appears to provide the potential for positve payoffs provided the equipment is matched to the user's needs.

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ABBREVIATIONS

The following abbreviations are used throughout this research report in order to simplify the presentation. Where a definition is required, the appropriate page number is listed.

B/W/C	Barley/Wheat/Canola
BCR	Benefit/Cost Ratio
CB	Cost Benefit
CF	Centrifugal Fan
CIF	Centrifugal In-Line Fan
hp	horsepower
IRR	Internal Rate of Return
MDA	Manitoba Department of Agriculture
mt	metric tonne
NPV	Net Present Value

I. INTRODUCTION

Harvesting under adverse weather conditions frequently results in a lower quality and quantity of grain production. Generally, the longer the grain is left standing or lying on the field, the higher the probability of damage from adverse weather. Moisture in the form of rainfall and heavy dew may lower the quality of grain through reductions in protein content, colour change, growth of mould, sprouting, as well as reduce the test weight of the grain. Tough or damp grain may also lead to spoilage or contribute to insect damage in storage, thereby reducing the value. Grain combined at higher temperatures may produce similar results in storage.

Post-Harvest Grain Storage Systems in Manitoba

In general, grain drying and aeration systems allow for earlier harvesting and the cooling and drying of grain for reduced risk of spoilage during storage. Farmers in Manitoba utilize a variety of systems for storing grain after harvest. The methods of storage used are part of the complete harvesting system and include:

- i) conventional non-aerated bins;
- ii) aeration bins;
- iii) natural air drying (NAD) systems;
- iv) heated air grain drying systems; and
- v) a combination of aeration, NAD and heated systems.

The simplest and least expensive of these systems is conventional storage in a non-aerated bin after the grain has been allowed to dry in the field. This is the most common method of grain storage in Manitoba. Each of the other systems involves increasing capital expenditures and greater management skills on the part of farmers although they allow greater flexibility at harvest, increase the effective length of the harvest season, and reduce storage risk.

Aeration refers to the movement of small volumes of air through the grain in order to eliminate temperature and moisture differences in the bin. The aim is not to remove moisture from the grain but rather to prevent the build-up of hot spots and moisture pockets where spoilage is more likely to occur. However, in the process of aerating the grain it is possible to lower the moisture content of the grain between 0.5 and 1 percent.[1] Aeration of grain typically involves airflow rates of between one and two litres of air per second per cubic metre of grain [1-2(L/s)/m3].

Although people frequently use the terms natural air drying and aeration interchangeably, the two are quite different concepts. Farmers using a NAD system harvest their grain in a tough or damp condition and dry the grain in the bin by passing ambient (i.e.,outside) air through the bulk. Airflow rates are much greater than for a grain aeration system as the main aim is to remove moisture as well as equilibrate temperature and moisture in the bin. The increased airflow rates required necessitate the use of larger, more expensive fans and a fully perforated floor in order to achieve even airflow distribution and prevent the occurrence of moisture pockets in the bin. A NAD system also requires closer monitoring compared to an aeration system in order to prevent either spoilage of the grain before it can dry or overdrying if the fan is left on too long.

Under a heated air grain drying system the grain is harvested at a higher moisture content and dried using artificially heated air. This system is the most expensive to acquire

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[1] Metzger, J.F. and W.E. Muir. "Aeration of Stored Wheat in the Canadian Prairies," Canadian Agricultural Engineering, Vol 25:1, 1983, pp. 127-137.

and operate and requires close supervision and monitoring. The advantage of a heated air grain drying system is that it extends the length of the harvest season to its maximum and permits greater flexibility in harvesting by allowing combining at higher moisture contents.

Some farmers use a combination of either aeration or NAD and heated air grain drying as part of their harvesting system. The grain dryer is used to remove the moisture from the grain which is then transferred to a bin equipped with either an aeration or NAD system for cooling and removal of the last 1 to 2 percent of excess moisture. This increases the efficiency and throughput of the grain dryer but also increases the required investment in, and management of, the system.

Objectives of the Study

Grain drying and aeration systems are a form of agricultural technology which have obvious benefits but which also involve significant costs. More complex systems presumably have greater benefits but also have greater costs. Installation of a grain drying or aeration system is an investment decision on the part of the farmer. The objective of this study is two fold. First, the study investigates the financial profitability of investing in a natural air dry system i.e., to determine if it is financially profitable for a farmer to install a drying system given the specific operating conditions and environment on the farm. The specific objective of the study is to determine the financial viability of installing a NAD system for three crops (wheat, barley and canola) at three locations (Winnipeg, Brandon and Dauphin) in Manitoba. The primary contribution of this study is to provide basic information for farmers in their decisions to either undertake or reject the extra cost of NAD equipment in their grain harvest and storage strategy. This objective is accomplished using a cost/benefit approach. A secondary contribution is the development of a computer software program that can aid farmers in their capital budgeting decisions. The computer program developed allows farmers, extension personnel, bin manufacturers, distributors and retailers to demonstrate the costs and benefits of NAD under particular circumstances outside of the analysis undertaken and reported in this study. The user will be able to enter information specific to his/her own operation, location and economic conditions to determine if investment in a NAD system is economically feasible. Use of the software in this way improves on the information provided in this report, which by necessity analyzed only "typical" situations.

Study Outline

The study proceeds with a discussion of the methodology used in the analysis followed by a description of the cost/benefit tableau developed. The profitability of different NAD systems under various conditions is then evaluated and the results of sensitivity analysis reviewed. In conclusion, the results are summarized and recommendations for further research suggested. A user's manual accompanies the cost/benefit tableau for NAD in the Appendices.

II. METHODOLOGY

The methodology used in this analysis is discussed below in regard to the conceptual framework, sampling frame of the analysis, data collection, time frame of the analysis, evaluation criteria used and scenarios analyzed.

Conceptual Framework

The methodology adopted in this analysis is that of traditional benefit/cost analysis used in the evaluation of an investment decision. A generalized flow chart of a typical harvesting system using NAD is shown in Figure 1. The conventional management approach in Manitoba is to swath the crop and allow it to dry in the field before combining. Adoption of a NAD system allows a farmer to combine the crop at a higher moisture content thus increasing the effective length of the harvest season or increasing the capacity of given harvest equipment. The grain is then placed in a NAD bin and dried down to an acceptable moisture content after which it can be either stored in the bin, sold or moved to another bin to permit the NAD bin to be used for drying another crop.

An Advanced NAD Management system is also illustrated in Figure 1. This system is "advanced" in the sense that the swathing operation is by-passed by straight cutting[2]. Some farmers may also use NAD in conjunction with a hot air grain dryer. The grain dryer is used to remove the moisture from the grain which is then transferred to a bin equipped with a NAD system for cooling and removal of the last 1 to 2 percent of excess moisture. Neither

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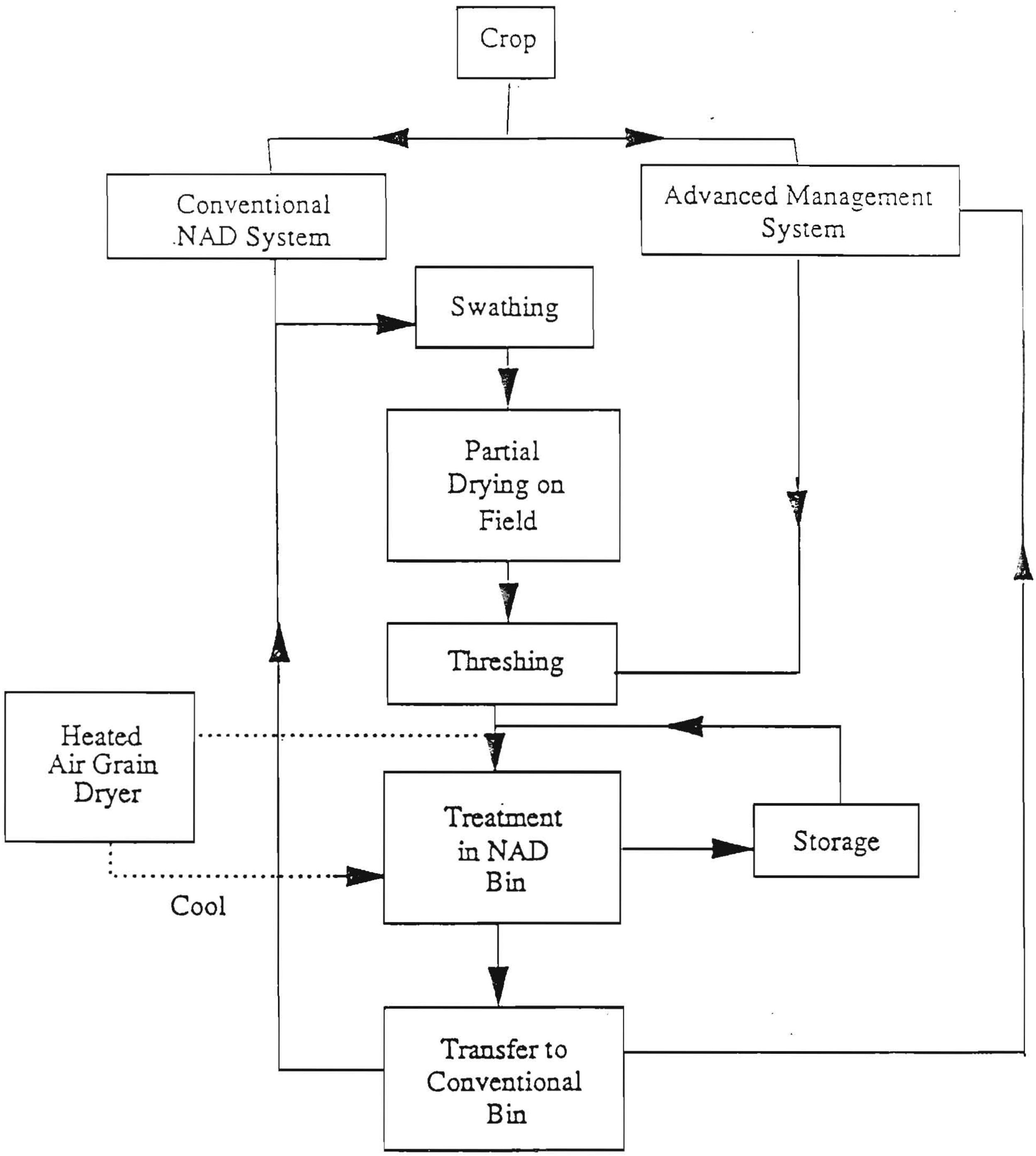
[2]Manitoba Agriculture, Direct-Cut Grain Harvesting and Drying. Manitoba Agriculture: Winnipeg, Manitoba, 1989.

Figure 1
Typical NAD Harvesting/Handling Systems

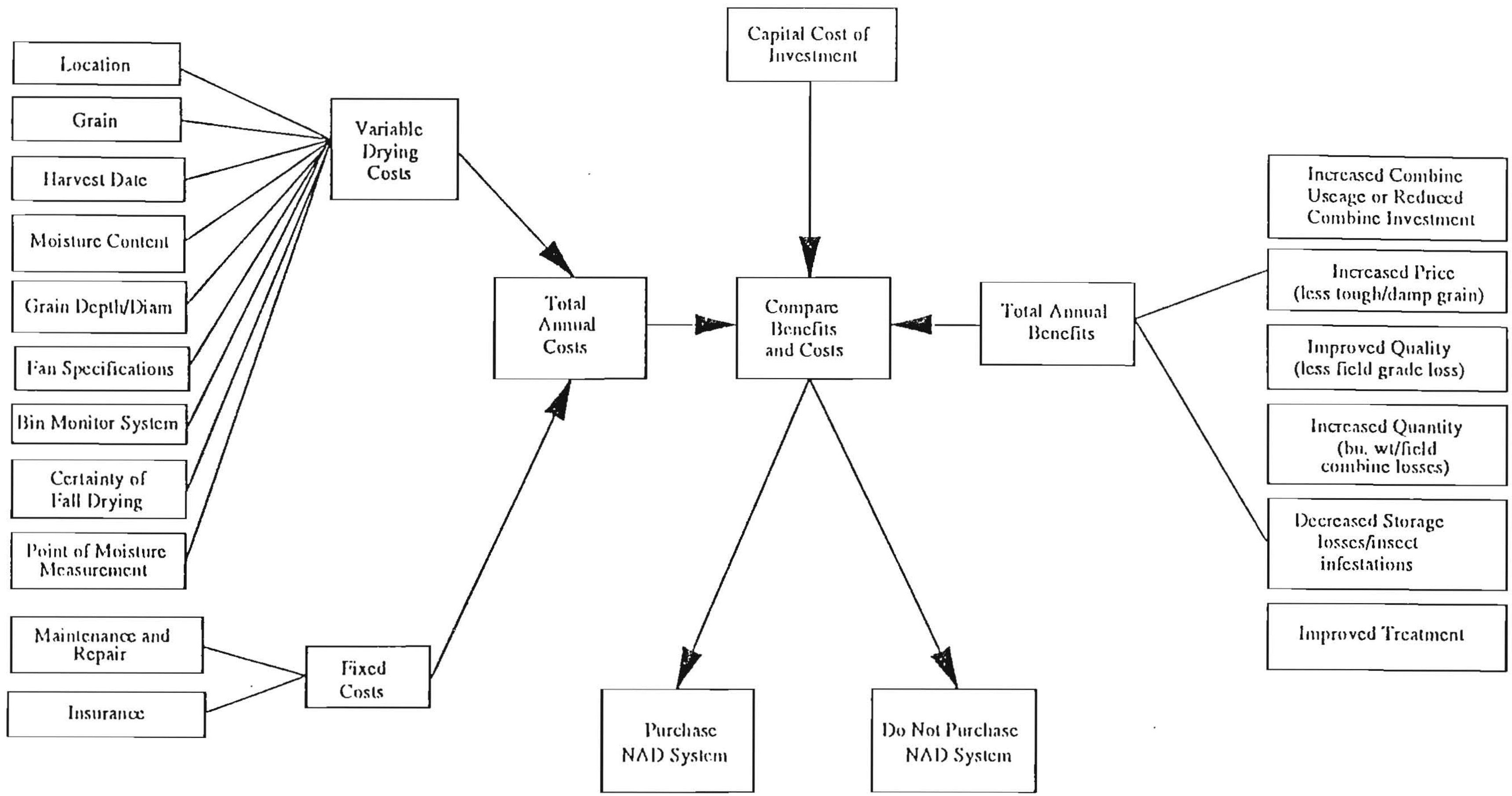


of these options was analyzed within this study because of lack of resources. However, they could be done using the same methodology.

On the basis of the flow chart shown in Figure 1, a framework was developed to encompass all of the relevant variables in the decision to purchase a conventional NAD system. This framework is presented in Figure 2. Each of the decision variables impacts either directly or indirectly on the costs and/or benefits of the NAD system. The left side of Figure 2 contains those variables having an impact on the cost of a NAD system while the right side highlights sources of expected benefits. Any costs and benefits of a NAD system are incremental to those occurring under a conventional harvest/storage system which does not use NAD. In other words, in evaluating the payoff to the extra equipment and costs associated with a NAD system, the costs and benefits of a non-NAD system are considered to be zero. This logic follows from the fact that most conventional bins used for grain storage today can be used with or without NAD capability.

The complete analysis requires the use of two computer programs. The costs of drying grain in the NAD bin were simulated by a computer program, "Grain Drying System Design" developed by Manitoba Agriculture (MDA). This program recognizes the fact that damp and dry weather will affect the length of time required for natural air drying, and the amount of overdrying that will occur. Based on average weather data at various locations in Manitoba, the computer program simulates drying and estimates drying operating costs under a variety of conditions. Those conditions affecting variable drying costs are indicated in Figure 2.

Figure 2
NAD Decision Framework



Using a computer spreadsheet program[3], the drying costs estimated by the MDA program along with other technical parameters specifying harvest conditions were entered into a cost benefit (C/B) program developed by the authors to estimate the costs and benefits of the system. These costs and benefits are then aggregated over time and are analyzed on the basis of a set of evaluation criteria to determine profitability of investment. The result is either a positive or negative evaluation of the system which the farmer can then use in his decision to purchase or not purchase a NAD system.

In conducting this analysis, it was often necessary to make simplifying, sometimes arbitrary decisions to limit the analysis to a feasible set of alternatives. The approach adopted throughout concerning parameters which might influence the results, was to assign values to parameters which would not favour positive economic returns. As a result, the economic results presented in this study are considered to be very conservative, ie., under full information or in actual application NAD may produce more favourable economic results.

Sampling Frame of the Analysis

This report analyses the costs and benefits of a NAD system for three crops (barley, wheat and canola) at three locations (Winnipeg, Brandon and Dauphin) in Manitoba. These combinations of commodity and location were chosen because they are the ones simulated by the MDA computer grain drying program. Additionally, they encompass the major grain growing regions in the province and as such are representative of conditions faced by most farmers in Manitoba.

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[3] "Quattro" products produced by Borland International Inc., Scotts Valley, California, copyright 1987.

Data Collection

Evaluation of NAD systems under Manitoba conditions involved collecting four types of data including:

i) precipitation data,

ii) fan and bin specifications and capital investment expenditure,

iii) input (electric power) and output (grain) price data and,

iv) technical parameters affecting benefits and costs such as the probability of a crop suffering a grade loss due to increased exposure in the field.

Precipitation data were required because of the impact of different harvest weather conditions on the quality and quantity of grain harvested in addition to effects on the grain after it is placed in storage. Grain harvested in a year when harvest conditions are dry, for example, may be of higher quality and drier than grain harvested in a wetter year. Thus the quality of the grain may be higher but the saleable weight of the grain may be reduced because of excessive drying in the field--1988 and 1989 conditions likely produced this result in Southern Manitoba.

In order to take account of the impact of weather conditions at harvest on costs and benefits, a rainfall probability distribution was calculated for each of the three locations (Winnipeg, Brandon and Dauphin) in the province based on the past 100 years (approximately) of rainfall data for the months of August and September. Possible harvest weather conditions were divided into dry (less than 90 percent of average precipitation), average (between 90 and 110 percent of average precipitation) or wet (greater than 110 percent of average precipitation). In Table 1. the probabilities of a dry, average or wet year entered in the CB tableau are illustrated.

TABLE 1. PRECIPITATION PROBABILITY DISTRIBUTION, BY LOCATION, AUGUST AND SEPTEMBER

Probability %	Winnipeg	Brandon	Dauphin
<90 (dry)	43.1	53.5	51.9
90<actual<110	19.0	15.2	18.2
>110 (wet)	37.9	31.3	29.9

Source: Derived from precipitation data obtained from Environment Canada

The technical parameters believed to vary with precipitation were weighted by rainfall probabilities[4] to provide an average estimate of the technical parameters. For example, the harvest season is extended with NAD consequently, it is possible that combine use may be increased. Following a two-step procedure, an average estimate of increased combine use in all years is calculated as follows:

1. Weighting the likelihood of increased combine use in dry, average and wet years 0.5, 1.0 and 1.5, respectively[5] by the probability of a dry, average or wet year occurring, (i.e., 0.43, 0.19 and 0.38 percent) results in an average likelihood estimate of increased combine time available.

2. The average likelihood can then be multiplied by the base probability of combine

[4] The MDA program uses its own historical weather patterns in determining drying costs. This includes temperature, humidity and precipitation data.

[5]Likelihood of increased combine use in a dry year is half (.5) that of an average year and 50 percent greater in a wet year (1.5) than an average year (1.0).

use (0.25 in the example below and defined as the percent of extra combining time the farmer will actually use), to determine the probability of increased combining use.

Probability of = Increased Combine Use	{0.25x[Probabilityx0.5)+(Probabilityx1.0)+(Probability x 1.5)]} dry year average year wet year

Further calculations allow the benefit associated with additional combining use to be valued.

Fan and bin specifications were required to simulate the various systems available to the farmer. While it was physically impossible to model every conceivable bin and fan combination in the analysis, a series of representative bin and fan combinations was developed and analyzed in order to give a relatively complete picture of NAD systems as they are used in Manitoba. Fan and bin specifications were obtained from MDA[6] and major bin and fan manufacturers in the province. All of the systems analyzed were for a bin with a fully perforated floor as this is the only type of drying system simulated in the MDA computer program.[7]

Based on the fans and bin sizes chosen, the capital investment in various NAD systems were determined. Dealers and manufacturers of different makes of bins and fans throughout the province were contacted in July 1989 for price data concerning the cost of fully perforated cereal and canola floors, supports, transition, vents, fans and stirring devices. Prices were collected for 1200, 1500, 3000, 5000, 7500 and 10000 bushel bins, 1.5 hp axial, 3, 5, 10, and 15 hp centrifugal and in-line centrifugal fans. The price of the bin and concrete pad was not

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[6] Manitoba Department of Agriculture, Fan Test Results, January 1987.

[7] Some NAD systems use a partially perforated floor which reduces the airflow rate and increases power requirements and drying time somewhat. For more information see Manitoba Department of Agriculture publication "Grain Aeration and Unheated Air Drying", 1987

included in the assessment of the capital cost of a NAD system as it is assumed the bin is already on farm or alternatively would be purchased for storage only. All price data were averaged for each bin size and fan category to determine capital investments representative of Manitoba. The capital cost of various components of a NAD system are listed in Table 2. Installation costs were added to the capital cost of the various components to arrive at a total investment cost.

To determine the benefits and costs of NAD, input and output prices were required. Grain prices, discounts, electrical prices/kwh and an estimate of combine operating margin were collected so that the benefits and costs associated with drying could be valued. This price information was gathered from a variety of sources.

The per unit electricity cost for drying grain in the bin was provided by Manitoba Hydro based on their 1989 fee schedule. Grain prices, and quality discounts were provided by local grain companies as their assessment of representative 1989 prices. The combine operating margin was partially based on the 1988 Manitoba Agriculture computer program "Combine Cost Analysis", version 3.0.

Technical parameters are non-price variables that attempt to 1) quantify the magnitude of some physical aspect of either harvesting or storage such as combine capacity or 2) quantify the probability of harvesting and storage losses expected under various weather conditions. Establishing values for the technical parameters (excluding the actual drying simulation which was accomplished through the Manitoba Agriculture program) proved to be the most difficult part of the analysis as there has been little or no research done on some of these parameters. Technical parameters were estimated through a review of the available literature, discussions with farmers, academic and industry experts and the authors' own experience with grain farming in Manitoba. A thorough explanation of the technical parameters and the assumptions used are discussed in the description of the CB tableau which follows the methodology section.

TABLE 2. ESTIMATED CAPITAL EXPENDITURE FOR VARIOUS COMPONENTS OF NAD SYSTEM.[1]

BIN EQUIPMENT	SIZE/PURCHASE COST					
	1200 bus.	1500 bus.	3000 bus.[3]	5000 bus.	7500 bus.	10000 bus.
BIN[2] FLOOR	$850	$850	$1150	$1700	$2000[2]	$2550[2]
TRANSITIONS AND VENTS	$240	$320	$350	$400	$420	$450
STIRRING DEVICES	NA	NA	NA	NA	$2500	$2600
FANS	1.5 hp AXIAL	1.5 hp CIF	3hp CIF	3 hp CEN	5 hp CIF	5 hp CEN
	$550	$750	$900	$1300	$1150	$1200
	10 hp CIF	10 hp[3] CEN	15 hp CEN			
	$1700	$2000	$2200			

[1] These prices are indicative of purchase costs as of June/July 1989.
[2] Prices are for canola floor. Discount $250 and $300 for cereal floor for 7500 and 10000 bu. bin, respectively.
[3] The size of equipment used in the base scenario.
CIF - centrifugal in-line fan
CEN - centrifugal fan

Time Frame of the Analysis

The first step in evaluating the profitability of a NAD system is to determine the projects planning horizon, that is the expected life of the system. The planning horizon is dependent on the economic life of the project and management's own risk preference. Over this period the investor can expect returns on the investment. In this study, the user is assumed risk neutral and a planning horizon of fifteen years was chosen on the basis of the expected economic life time of the equipment comprising the NAD system.

The analysis is based, as far as possible, on July 1989 technical and price conditions and is extended to cover the expected investment period of 15 years. All costs, for example, are based on 1989 costs although the spreadsheet can accommodate changes in the real prices of the three crops as well as different levels of costs and values for most of the important factors. The technical parameters can be set by the user but were held constant over the entire life of the investment for purposes of the analysis.

Evaluation Criteria

Before any decision to invest in a NAD system is made, the initial capital outlay, future capital expenditures on the system and expected net returns over the life time of the system must be assessed. The investment is economically feasible if the project returns the initial capital investment and a reasonable interest return. Whether the investment will be actually made depends not only on its' ability to payback the initial investment but on total expected returns relative to returns that could be earned on alternative investments.

Given initial capital investments and the returns over the life of alternative investment projects, projects must be evaluated and ranked according to their profitability. Several techniques are available to evaluate projects, however, as the results are often inconsistent with each other, one technique does not assure appropriate project evaluation choice. Consequently, this analysis uses three criteria to evaluate the NAD investment decision, net present value, benefit/cost ratio and internal rate of return.

Net Present Value (NPV)

The net present value (NPV) method recognizes the time value of money and discounts future cash flows by some discount rate believed to equal the time value of money. Gwartney and Stroup provide an excellent explanation of net present value. NPV is " the current worth of future income after it is discounted to reflect the fact that revenues in the future are valued less highly than revenues now. Economists use the term discounting to describe the procedure of reducing the value of a dollar to be received in the future to its present worth. Clearly, the value of a dollar in the future is inversely related to the interest rate."[8]

To illustrate these concepts, the value of a flow of $1,000 received annually over 15 years is $21,579 at the end of the 15 years based on an interest rate of 5 percent. This is called the future value of the flow of revenues. Alternatively, the value today (present value) of $1,000 received annually over the next 15 years discounted at 5 percent is $10,380. If $10,380 were invested at 5 percent for 15 years, the value at the end of the 15 years would be $21,579.

In the cost/benefit analysis, the annual operating costs and annual benefits are calculated and the net benefit derived by subtracting operating costs from benefits. The annual net benefits which represent a flow of net benefits over fifteen years are discounted using a discount rate of 5 percent to determine the present value. If the present value (worth) of the

[8]James D. Gwartney and Richard L. Stroup, Microeconomics: Private and Public Choice. 4th ed., Academic Press: New York, 1987, p. 307

NAD system installed exceeds the capital investment cost, then the NPV will be greater than zero. The investment is considered a favourable one if the NPV is a positive number as the benefits outweigh all the costs yielding positive returns to the investor.

Weaknesses of this technique usually include subjective choice of the discount rate and the variability of the project rankings with the discount rate. The weaknesses, however, in this study are minimized as the flow of net benefits are equal over the life of the investment. Only when the flow of annual benefits vary over the life time of the project (in the case of a NAD system, the grain combinations dried annually would vary resulting in variable returns annually) should NPV be used cautiously in evaluating investment alternatives.

Benefit-Cost Ratio (BCR)

Benefit/cost ratio is a measure which compares the present worth of the flow of annual benefits of the investment with the present worth of the annual operating and capital costs of the investment, expressed as a ratio. For instance if the present value of the stream of annual benefits and costs were $9,500 and $3,000 respectively, and the capital investment $4,000, the BCR would be 1.36, i.e.

$$\$9,500/\ (3,000 + 4,000) = 1.36$$

A ratio greater than 1.0 indicates that the benefits exceed the costs (after recognizing the time value of money) and the investment is considered profitable. In choosing among alternatives, the investment project with the highest BCR would often be chosen first as the proportion of benefits to costs is greater.

Internal Rate of Return (IRR)

The internal rate of return is the discount (real interest) rate at which the present value of the net benefits of the investment is just equal to the cost of the investment. This means the NPV would be zero as the present worth of the net benefits less the cost of capital investment would be zero if the two values were equal. For instance if the net benefits for a particular NAD system were $1,005 annually for fifteen years, a discount rate of 16 percent would be required to reduce the present value of the flow of net benefits to $5,500. Subtracting the capital cost of $5,500 for a 3,000 bushel bin using a 10 hp centrifugal fan, the NPV would be zero and the BCR 1.

The importance of the IRR calculated is that it can be compared to the interest rate that could be earned on alternative financial investments. Frequently, it is used to rank projects or investment profitability. If other investment alternatives yield a better return on investment then they should be chosen. For instance, if the IRR for project one were 16 percent, and the IRR for project two 12 percent, project one may be chosen as it provides a higher return on the investment.

Scenario Selection

While this project was not difficult to research from a conceptual standpoint, the number of parameters specifying the NAD system and conditions of harvest presented innumerable combinations that could be analyzed. For instance, the Manitoba Agriculture natural air drying program requires the user to make a minimum of ten choices. Crop, location, size of bin, fan, harvest date, initial moisture, place of final moisture measurement, price of grain, price of electricity, and humidistat control must be specified to determine the cost of air drying and the drying time required. These are all relevant decisions which farmers might consider in budgeting a NAD system. However, from the analytical standpoint, if we limited our analysis to:

- three crops (wheat, barley and canola),

- three locations (Dauphin, Brandon and Winnipeg),
- six bin sizes (1200, 1500, 3000, 5000, 7500 and 10000 bushels),
- four moisture levels (1,2,3,and 4 percent above dry),
- moisture measurement at either the top layer or on an average bin basis,
- two harvest date choices and,
- only one price for each grain and electricity,

There would be 2,592 combinations of equipment and situations to analyze with this limited set of variables. Obviously the feasible combinations in the province are much more numerous, as there is a spectrum of prices, many models, sizes and configurations of bin and fans, and moisture levels and harvest dates options which can be combined in a variety of combinations. Consequently, it was necessary to make particular choices to complete the analysis.

To provide representative results and give as complete a picture as possible of the economics of natural air grain drying in Manitoba, the authors adopted a case study approach to the problem. Specific combinations of bins and fans were selected to represent the range of different production practices in the province. The results thus obtained are not intended to be exhaustive but rather to present a reasonably accurate representation of the economics of NAD in the major grain growing regions of the province and to provide information on realistic alternative combinations of conditions.

As indicated earlier, the primary objective of the study is to determine the financial viability of installing a NAD system for three crops, barley, wheat, and canola. A base scenario was chosen consisting of a 3000 bushel bin[9]. A 10 hp centrifugal fan was chosen because it would dry one batch each of 18.8 moisture content barley, 18.5 percent wheat and 12.0 percent canola consecutively down to 14.8, 14.5 and 9.0 percent moisture, respectively. The bin floor, fan, supports, vents and installation costs of this base NAD system was estimated to cost $5,500. This is a relatively constrained system but it is one which was considered suited to commercial conditions in Manitoba for comparative analytic purpose.

Three harvest dates August 15, September 7 and October 1 were chosen for each crop. The base scenario was then tested to see if the NAD system under the conditions specified could dry the different grains within the time frame allocated. Barley must be dried within 23 days of harvest to make room for wheat which is harvested September 7. Similarly, the batch of wheat must be dried within 24 days so that the canola could be dried. Within the base scenario, the remaining parameter choices included:

1. a Winnipeg location
2. a fully perforated canola floor,
3. no humidistat control, continuous fan operation,
4. moisture measured at the top of the bin and,
5. barley, wheat, canola and electricity priced at 1989 on-farm prices of $110, $150, $280/tonne and $0.0406/kWh, respectively.

While the moisture levels may appear excessive, and the base NAD system expensive given the constraints imposed, the level of parameters and system specifications were chosen so as to ensure no bias in favour of the profitability of natural air drying.

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[9] The bin dimensions chosen for each bin size category are based on bushels filled to the apex of the bin. However, the actual grain dried and consequently the subsequent cost benefit analysis done are based on grain volumes level to the eaves.

Other scenarios were analyzed to determine the feasibility of NAD systems under different conditions[10] such as:

1. Location - Brandon, Winnipeg and Dauphin.
2. Bin sizes - 1200, 1500, 3000, 5000, 7500 and 10000 bushel bins.
3. Bin configuration - differences in depth and diameter within the same bin size category.
4. Fan choices - size of fans and type of fan, centrifugal vs. in-line centrifugal vs axial.
5. Harvest dates- alternative dates for harvest included barley August 20, wheat September 10, and canola September 15.
6. Place of moisture measurement - top versus average bin moisture.
7. Humidistat control - no humidistat control (100 percent fan operation) versus 60 percent humidistat control which allows the fan to run when humidity levels fall below 60 percent.
8. Flooring - canola and cereal.[11]
9. Combination of crops dried- barley/wheat, wheat/canola, barley/canola and each crop separately.

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[10]Not all combinations of the listed conditions list were undertaken due to the sheer magnitude of scenarios that would result. Only specific combinations of different conditions were chosen to exemplify the economics of a NAD system. The actual scenarios undertaken are listed in Table 5.

[11] The MDA computer program to determine the variable cost of natural air drying is based on the assumption of a full floor, consequently scenarios using partial floors could not be undertaken.

III. COST/BENEFIT TABLEAU

The following section of the report describes the cost/benefit (C/B) tableau developed, to acquaint the reader both with data requirements and operation of the program, and facilitate interpretation of the analytical information generated. A sample of the C/B tableau developed to determine the profitability of NAD is illustrated in Table 3. It is divided into eight segments, segments 1 to 4 used primarily to enter information required for calculating the costs, and segments 5 through 8 to calculate the benefits and evaluation criteria.

The program has been constructed to allow the user to enter his/her own parameter estimates over the expected life of the NAD system. The scenarios analyzed in the study assume a fifteen year life span, however, the user has the option of reducing the expected life of the system being studied. In addition, the user may either i) choose parameters he believes representative or an average of crop and economic conditions in his area and apply that information over the investment period or ii) change parameters for any year or years to accommodate his/her own unique circumstances leaving the parameter values in subsequent years unchanged.

SEGMENT 1

Precipitation probabilities are entered in Segment 1. In order to take account of the impact of weather conditions at harvest on costs and benefits, a rainfall probability distribution for the relevant geographical location is necessary. The precipitation probabilities can be those supplied in the text or the user's own opinion of precipitation patterns. In Table 3, the probability of a dry, average and wet year in Winnipeg are 43, 19 and 38 percent, respectively. These probabilities are used to weight those parameter estimates that vary with

TABLE 1. COSTS AND BENEFITS OF NATURAL AIR GRAIN DRYING

SECTION 1. Real Price Ratio	Barley	Wheat	Canola
Real Price Ratio: (Year t/Year t-1)	1.00	1.00	1.00

			FAN ID
FLOORING CANOLA: MOISTURE MEASURE TOP			206
Weather Conditions	Year 1		DRY TIME
Probability of a dry year	0.43	BARLEY	14
Probability of an average year	0.19	WHEAT	21
Probability of a wet year	0.38	CANOLA	24

SECTION 2. Technical Parameters	Batch No.1	Batch No.2	Batch No.3
MDA Computer Simulation Parameters			
1. Location	-------------	Winnipeg	-------------
2. Crop	Barley	Wheat	Canola
3. Harvest Date	Aug.15	Sept.7	Oct.1
4. Moisture Content at Harvest (%)	18.80	18.50	12.00
5. Price (No.1) ($/mt)	110.00	150.00	280.00
6. Bin Size (tonnes) (3,000 bu)	66.00	82.00	68.00
7. Bin Diameter (metres)	5.50	5.50	5.50
8. Grain Depth (metres)	4.50	4.50	4.50
9. Quantity Dried (tonnes)	66.00	82.00	68.00
10. Airflow (1/sec/cu m)	19.70	19.20	15.50
11. Fan Operating Cost ($)	116.00	179.00	209.00
12. Bin Overdrying Cost ($)	96.00	148.00	299.00
13. Average Bin Moisture	13.70	13.50	8.70

SECTION 3. Other Parameters			
14. Use Rate (batches dried/year)	1.00	1.00	1.00
15. Combine Operating Margin ($/hr)	70.00	70.00	70.00
16. Combine Capacity (mt/hr)	10.00	10.00	10.00
17. Base Prob. of Cimbine Use	0.25	0.25	0.25
18. Prob. of Increased Combine Use	0.24	0.24	0.24
19. Discount for Tough Grain ($/mt)	6.00	7.00	15.00
20. Discount for Damp Grain ($/mt)	6.50	7.50	--
21. Damp/Tough Ratio	0.19	0.19	--
22. Base Prop. of Harvest Tough/Damp	0.15	0.15	0.10

23. Proportion of Harvest Tough/Damp	0.14	0.14	0.10
24. Base Prob. of Grade Loss	0.25	0.25	0.05
25. Prob. of Grade Loss	0.22	0.22	0.04
26. Discount for Grade Loss ($/mt)	5.00	3.00	13.00
27. Probable Discount for Grade Loss ($/mt)	5.00	5.28	13.00
28. Reduced Combine Losses (%)	1.80	1.80	1.80
29. Base Weightloss Due to Weather (%)	3.00	3.00	0.00
30. Weightloss Due to Weathering (%)	2.85	2.85	0.00
31. Excess Handling Cost ($/mt)	1.50	1.50	1.50
32. Base Probability of Storage Loss (%)	0.50	0.50	2.00
33. Probability of Inc. Storage Loss (%)	0.49	0.49	1.95
34. Base Prob. of Insect Damage (%)	0.50	0.50	0.50
35. Prob. of Inc. Insect Damage (%)	0.49	0.49	0.49

COSTS OF NATURAL AIR DRYING SYSTEM

SECTION 4. Capital Costs	Year 1 Value
Electrical Service Installation	2000.00
Perforated Floor & Supports (Canola)	1150.00
Fan and Stirring Devices	2000.00
Transition and Vents	350.00
Total Capital Costs	5500.00

SECTION 5. Annual Operating Costs	Batch No.1	Batch No.2	Batch No.3
Fan Operating Costs (from simulation)	116.00	179.00	209.00
Repair and Maintenance	99.60	99.60	99.60
Insurance (1% of Capital Cost)	18.33	18.33	18.33
Excess Handling (based on use rate)	99.00	123.00	0.00
Overdrying Costs (from simulation)	96.00	148.00	299.00
Total Annual Operating Costs	428.93	567.93	625.93

BENEFITS OF NATURAL AIR DRYING SYSTEM

SECTION 6. Benefits Accrued	Batch No.1	Batch No.2	Batch No.3
Increased Combine Usage (hrs x $/hr)	112.61	139.91	116.03
Increased Sales of Straight Grades	68.05	98.45	96.90
Reduced Weather Damaber (grade)	71.57	93.90	38.34
Reduced Overdrying in Field (0.5%)	46.32	78.47	128.20
Increased Quantity Harested			

Reduced Combine Losses	130.68	221.40	342.72
Reduced Weightloss from Weathering	44.87	76.03	0.00
Decreased Storage Losses	35.39	59.96	371.28
Decreased Insect Infestations	35.39	59.96	92.82
Improved Treatment in Bin	0.00	0.00	0.00
Total Annual Benefits	544.88	828.08	1186.29

SECTION 7. Summary of Annual Benefits

	Year 1
Total Annual Costs	1622.80
Total Annual Benefits	2559.25
Annual Net Benefit	936.45
Annual Benefit Cost Ratio	1.58

CUMULATIVE SUMMARY OF RESULTS

	Year 0	Year 1	Year 2
Investment and Annual Cost	5500.00	1622.80	1622.80
Annual Benefits	0.00	2559.25	2559.25
Annual Net Benefit	-5500.00	936.45	936.45

SECTION 8. Evalutation Criteria (Years 1 to 15)

Real Opportunity Cost of Capital (%)	0.05
Net Present Value ($)	4220.03
Internal Rate of Return	0.15
Benefit-Cost Ratio	1.19

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROBABILI OF GRADE LOSS

	NPV	IRR	BCR
	4220.03	0.15	1.19
0.10	3161.78	0.13	1.14
0.15	3514.53	0.13	1.16
0.20	3867.28	0.14	1.17
0.25	4220.03	0.15	1.19
0.30	4572.78	0.16	1.20
0.35	4925.53	0.16	1.22
0.40	5278.28	0.17	1.24
0.50	5983.78	0.19	1.27

weather conditions at harvest. Technical parameters weighted by the rainfall probabilities include **Probability of Increased Combine Use, Damp/Tough Ratio, Proportion of Harvest Tough/Damp, Probability of Grade Loss, Weight Loss due to Weathering, Probability of Increased Storage Loss and Probability of Increased Insect Damage.**

SEGMENT 2

Segment 2 contains technical parameters provided by the MDA computer simulation of a NAD system. A column is provided for each grain (barley, wheat and canola) to list the results of each MDA grain drying simulation and to allow the benefits and costs for each grain to be determined independent of the other two. This introduces flexibility into the program allowing different combinations of grain drying to be tested, for example barley/wheat/canola, barley/wheat, barley/canola, wheat/canola, as well as barley, wheat and canola individually. Many of these technical parameters are incidental to the actual cost/benefit analysis undertaken in the C/B tableau[12] and are listed only for reference purposes. However, the other technical parameters such as crop price, bin size, fan operating cost and bin overdrying cost are required in the cost/benefit analysis. An explanation of these parameters and their role in the cost benefit analysis follow.

Crop Price. The user must assign a per tonne price for each grain to be dried. Price is used to determine the monetary level of benefits and costs such as reduced overdrying in field, reduced combine losses, reduced weight loss, decreased storage losses, decreased insect infestation and overdrying costs. The price may reflect a producer's average price expectations, or a series of forecast prices over the life of the system. In Table 3, prices of

[12] While incidental to the cost/benefit analysis this information is pertinent to the level of fan operating costs and bin overdrying costs.

$110, $150 and $280 were chosen for barley, wheat and canola, respectively.

Bin Size. The bin size (quantity dried) is taken to be the volume of grain contained in the bin if filled **level with the eaves.** While many bin sizes were analyzed, the cost benefit results indicated in Table 3 are for a 3,000 bushel bin. Multiplying the annual benefit per tonne by the quantity of grain dried per batch gives the annual benefit per batch of grain dried. The stream of annual benefits over the life of the system are discounted to determine the present value of total benefits.

Fan Operating Cost. This is the electricity cost of drying grain in the NAD system specified, and is calculated by the MDA computer simulation program. It is one of the components of annual operating costs. The fan operating costs for barley, wheat and canola were estimated at $116, $179 and $209 respectively by the MDA computer program for the 3,000 bushel bin/10 hp centrifugal fan NAD system analyzed in Table 3.

Bin Overdrying Cost. Current technology does not allow easy monitoring of the exact moisture content of grain in the bin. As a result grain dried in a NAD system will frequently be overdried in the lower layers if the moisture content is measured at the top of the bin[13]. The MDA computer simulation program calculates this cost on the basis of the average moisture content of the grain and the grain price set by the user. This also is one component of annual operating costs. In Table 3 overdrying costs were $96 for barley, $148 for wheat and $299 for canola.

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[13]The average moisture content can be 1 to 2 percent below the moisture content in the top layer when the top layer is chosen as the point of moisture measurement which terminates the drying process.

SEGMENT 3

User-entered Technical Parameters

Some of the technical parameters in Segment 3 must be entered by the user so that the remaining technical parameters can be calculated. The following are technical parameters which the user must set based on his/her experience and industry statistics:

1) use rate
2) combine operating margin
3) combine capacity
4) base probability of combine use
5) discount for tough grain
6) discount for damp grain
7) base probability of harvest tough/damp grain
8) base probability of grade loss
9) discount for grade loss
10) reduced combine losses
11) base weightloss due to weather
12) excess handling costs
13) base probability of storage loss
14) base probability of insect damage

For the purpose of the study, the technical parameters were estimated through a review of available literature, discussion with farmers, academic and industry experts and the authors' own experience with grain farming in Manitoba.

The following discussion defines the technical factors, indicates how they are used and presents the technical parameter values used in the analyzes. <u>In the discussion, it is important to distinguish between base probability of a technical parameter which the user sets, and the probability of the same parameter which is calculated using precipitation probabilities and the base probability set by the user.</u>

Use Rate. The user must indicate for each year of the investment period and each grain whether or not the NAD system will be used to dry a batch of that grain. A value of one instructs the computer to calculate the costs and benefits associated with drying a batch of the specified grain. Conversely, a value of zero indicates that the NAD system would not be used to dry the specified grain. For example in Table 3, a use rate of 1 was indicated for all three grains, barley, wheat and canola. A use rate of 1 for barley and canola, and 0 for wheat would indicate that the system would be used to dry barley and canola only. Alternatively, the user may wish to dry only one batch per bin to avoid handling. In this case, only the grain he/she wished to dry would have a use rate of 1 while a zero use rate would be displayed for the two remaining grains.

Incorporating use rates in the cost/benefit program increased the program's flexibility. The decision on how many batches to dry is best left to the user. He/she are then able to choose the scenario which best matches their own on-farm situation. Hopefully, the result is increased practicality, relevance and acceptability to farmers in Manitoba. It should be noted, however, that even in the driest year, at least one grain should be dried in the system. Grain can still be harvested at higher moisture levels to reduce overdrying in the field and hedge against changes in weather.[14]

Combine Operating Margin. This parameter is used in the formula to estimate the extra revenue (income less expenses) that could be earned by a farmer if he were to hire out his combine to other farmers (or if he were able to purchase a smaller combine). A combine operating margin of $70.00/hour was used in Table 3. The results of this study indicate that the benefits accrued through increased combine use is one of the larger sources of benefits associated with NAD.

Combine Capacity. Combine capacity is the number of metric tonnes per hour that

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[14]This approach to natural air drying was suggested by O. Friesen, agricultural engineer, Manitoba Agriculture.

a farmer can harvest. In the scenarios analyzed, a combine capacity of 10 metric tonnes per hour was assumed. A modern combine, pull-type or self propelled, could be expected to harvest this volume under favourable harvest conditions.[15] Combine operating margin and base probability of combine use are all used to determine the benefits generated through increased combine use.

Base Probability of Combine Use. Installing a NAD system increases the number of hours a combine can be used in any harvest season. The base probability is that percent of the extra combining hours created in an average year, the farmer believes he will make use of. In Table 3, a base probability of combine use of 25 percent is used indicating that the farmer can expect to utilize only 25 percent of the extra combine hours made available when a NAD system is used.. This parameter is then used to determine the probability of combine use which considers the probability of increased combine use under different harvest weather conditions.

Discount for Tough and Damp Grain. The user must assign a discount for tough grains, and specify additional discounts for damp grain. For example, a discount of $6.00/metric tonne was indicated for barley in Table 3 and an additional discount of $6.50 raising the total discount for damp grain to $12.50 per tonne. Together with the damp/tough ratio and the proportion of grain harvested either in tough or damp condition, the benefit of increased sales of straight grades is determined.

Base Probability of Harvest Tough/Damp. This parameter indicates the proportion of grain harvested as tough or damp in an average year and is used to calculate an estimate

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[15]A combine with this capacity would have a 9 to 10 m^2 separation area. According to MDA " Rental and Custom Charges for Farm Machinery" the JD 7700, MF 850, and NH 1500 series have separation areas in this range.

of the average proportion of grain harvested as tough and damp under different harvest weather conditions. For the study it was assumed that 15 percent of wheat and barley crops are harvested as damp or tough, and 10 percent for canola in an average year.

Base Probability of Grade Loss. This parameter refers to the incidental proportion of grain harvested and placed in a NAD system that would have suffered a grade loss due to excess moisture after maturation (ie., the reduction in the proportion of grade loss as a result of earlier harvesting). If the parameter is set at 0.25, in an average year, an additional 25 tonnes out of every 100 tonnes would have suffered a grade loss if left to dry in the field.

Discount for Grade Loss. For barley and canola this parameter is equal to the price difference between number 1 and number 2 as it is not common for either of these crops to lose a grade because of weathering. Discounts of $3.00 and $13.00 for barley and canola were representative of the price difference between grades 1 and 2 during June/July 1989. A wheat discount rate of $3.00 from grade one to grade two was quoted for July 1989. However, it is necessary to account for the possibility of the grade falling from number 1 to number 3 for wheat. This possibility is addressed in the technical parameter "probable discount for grade loss".

Reduced Combine Losses. Harvesting grain at higher moisture content reduces combine losses, especially through cracking as the grain is less brittle. This parameter together with the price of the crop reflects the value of the benefit. If harvesting at higher moisture content can increase the volume of canola harvested by 2 percent, the benefit of the NAD system assuming $300/tonne canola and 68 tonnes dried, is estimated at $408, i.e., 2 percent of $300/tonne for 68 tonnes.

A reduced combine loss value of 1.8 percent in Table 3 is considered conservative.

Prairie Agricultural Machinery Institute reported that standard combine loss were 4.5 percent lower in tough Neepawa than dry[16]. A Saskatchewan study[17] similarly estimating the cost advantages of natural air drying, assumed combine losses would be reduced 2.23 percent when harvesting high moisture wheat, a reduction of .73 percent on shoe loss and 1.5 percent cracking loss. These numbers appear excessive but if they are accurate our methodology again understates the contribution of natural air drying.

Base Weight Loss Due to Weather. Excess moisture after maturation can cause barley and wheat to lose weight as well as grade. This parameter is used to calculate an average estimate of weight loss due to weathering based on rainfall probabilities. The 3.0 percent weightloss used in Table 3 represent only 1.4 pounds per bushel of barley and 1.8 for wheat; again these are conservative estimates. There are no estimates of weight loss in canola, however, researchers contacted felt that there was likely to be little weight loss due to excess moisture.

Excess Handling Costs. If the NAD system is used to dry more than one crop per year there is a cost associated with shifting the grain from the bin to another bin (assuming the grain is not hauled to market). Excess handling costs are determined from this technical parameter in conjunction with tonnes dried (bin size). For example, an excess handling cost of $1.50/tonne charged against 66 tonnes results in excess handling costs of $99.

Base Probability of Storage Loss. Grain stored in a nonaerated bin is more subject

[16] Prairie Agriculture Machinery Institute, Edwards Model GN - R78-46 Rodweeder. Report #R 180, January 1981.

[17] Saskatchewan Agriculture, Economics of Natural Air Grain Drying. Farm Management Section, Economics Branch, Saskatchewan Agriculture: Regina, March 1987. pp.4-6

to damage from mould or fungus because of the possibility of pockets of heat or moisture occurring. This parameter is used to calculate probability of increased storage loss which in turn is used to estimate the benefit of decreased storage losses. Statistical estimates of these parameters were unavailable, however, estimates of half of one percent (.5%) used for wheat and barley and 2 percent for canola are considered conservative.

Base Probability of Insect Damage. Grain stored in nonaerated bins is also more subject to damage from insects because of the potentially warmer and wetter conditions in these bins. The probability of insect damage and the benefits of reduced insect infestation are based on this parameter. Again, statistical estimates were unavailable and a conservative estimate of .5 percent used.

Derived Technical Parameters

The remaining technical factors in this section are derived from the technical parameters discussed above and are strictly determined by the formulas programmed in the C/B tableau. The following discussion indicates how they are derived.

Probability of Increased Combine Use. The likelihood of increased combine use in dry, average and wet years is set at 0.5, 1.0 and 1.5, respectively where the likelihood of increased combine use in a dry year is half (0.5) that of an average year (1.0) while in a wet year it is 50 percent greater (1.5) than an average year. These likelihoods are then weighted by the precipitation probability of a dry, average and normal year to derive an estimate of the average likelihood of increased combine use. The average likelihood can then be multiplied by the base probability of additional combine use to determine the probability of increased combine time. A probability of increased combine use of 24 percent was calculated and listed in Table 3. This parameter acts together with combine operating margin to reflect this benefit in either increasing revenue generation or reducing the required investment in the combine.

Damp Tough Ratio. The ratio indicates the breakdown of grain harvested above acceptable moisture content. For example, a base value of 0.25 indicates that in an average year, for grain harvested above the allowable moisture content for straight grades, 75 percent is tough and 25 percent is damp. This base value is adjusted to account for expected weather conditions at different locations in the province using precipitation probabilities in Table 1.

Proportion of Harvest Tough/Damp. The base proportion indicates the proportion of grain harvested as tough or damp in an average year, for example 0.15 for barley. In a dry year the likelihood of tough/damp grain is expected to be zero whereas the likelihood of tough/damp grain in a wet year are estimated to be double that of an average year. These likelihoods are multiplied by the rainfall distribution patterns to yield an average likelihood. This estimate is then multiplied by the base proportion of harvest tough/damp to derive an average estimate of the proportion of grain harvested tough or damp. Values of 14 percent for barley and wheat, and 10 percent for canola are listed in Table 3.

Probable Discount for Grade Loss. The probable grade discounts for barley and canola are simply the price difference between number 1 and number 2 listed under the technical parameter "discount for grade loss". However, the possibility of wheat falling two grades must be considered. The likelihood that wheat will grade number 3 in wet years was assumed to be three times greater than in an average year. Multiplying by the rainfall distribution results in an estimate of the average grade reduction which when multiplied by the discount rate for each grade, yields an average discount rate per tonne. In the base scenario analyzed in Table 3, a probable discount of $5.28/tonne was estimated for wheat.

Probability of Grade Loss. Like the other probability parameters, it too is based on its base probability, weather probabilities and the likelihood of grade loss in dry and wet years relative to the average year. It is assumed in the study that the likelihood of a grade loss in a dry year is one quarter that of an average year and 50 percent greater in a wet year than an average year. The likelihoods of a grade loss are multiplied by precipitation probabilities and the resulting average likelihood by the base probability of a grade loss to derive the probability of a grade loss. This parameter acts together with the discount for grade loss to reflect the value of this benefit. For example, a 5 percent probability of grade loss for canola, on 100 tonnes at a discount of $13.00/tonne results in a revenue loss of $65.

Weight Loss Due to Weathering. Weight loss due to weathering is assumed to be zero in dry years and double that of an average year in wet years. These likelihoods, as in the other parameters, are multiplied by precipitation distributions to derive a weighted average likelihood. This estimate is then multiplied by the base weight loss due to weathering chosen by the user to determine an estimate representative of weight loss due to weathering for all years. A weightloss of 2.85 percent was estimated for barley and wheat.

Probability of Increased Storage and Insect Damage. The likelihood of storage losses and insect damage in dry, average and wet years of 0.5, 1.0 and 1.5 respectively, are multiplied by precipitation probabilities to determine the average likelihood of storage losses and insect damage. The base probability of storage loss and insect damage, .5 percent in Table 3, are then multiplied by the average likelihood to determine the probability of increased storage loss or insect damage, 49 percent in Table 3 for barley and wheat. Both these probabilities are multiplied by the volume of grain dried and the price per tonne to derive the benefits of decreased storage loss and insect infestation.

SEGMENT 4

The cost of electrical service installation and the investment cost of a NAD system are entered in section four on capital costs. For the study, the costs were based on an average of industry quotes. The user, however, could enter the purchase price quoted by either the dealer or manufacturer of the system he was considering.

In Table 3, electrical service installation costs were assessed at $2,000, perforated canola floor at $1,150, $2,000 for the 10 hp centrifugal fan and $350 for the transitions and vents. If power to the bin sites or a fan acquired in the past for aeration purposes were sufficient, a value of zero would be entered for the fan and electrical service installation.

The user also has the option of replacing equipment and including its capital cost at the time of purchase in the analysis. For example, the user may wish to replace a fan in the eighth year and determine the profitability of his/her proposed NAD system. As the expected life of a fan and bin are unequal, the bin life exceeding that of fans, both the fan and bin were assumed to have a fifteen year life expectancy in the study.

SEGMENT 5

Section 5 calculates and summarizes the annual operating costs of the NAD system being analyzed. The fan operating and overdrying costs are carried forward from Segment 2. The excess handling costs are based on the excess handling cost per tonne multiplied by the quantity of grain dried. Insurance costs are automatically set at 1 percent of the installed cost of the system and are apportioned to each batch dried on the basis of use rate. That is if only one batch of grain were dried, the insurance cost of the NAD system would be charged fully against that batch. If two or three batches were dried then the insurance cost would be split equally two or three ways. As three batches were dried in the base scenario indicated in Table 3, each grain was allocated an equal insurance cost assessment of $18.33.

Annual repair and maintenance costs are assumed to be 8 percent of the original installed cost for the perforated floor, supports, transition and vents, and 3 percent of the fan purchase price. These costs are adjusted on the basis of the number of batches dried each year in order to reflect the fact that these costs increase with use. If the NAD system is not used in any one year the fixed costs of repair and maintenance are apportioned equally between each of the three batches.[18]

[18]If in one year the NAD system were not used, there would be no benefits but operating costs such as repairs, maintenance and insurance costs would still be incurred. This would result in a negative net benefit which would be calculated into the evaluation criteria. Note that in such a scenario, the user would have to determine how many years out of the fifteen he/she believed the NAD system would not be used and determine which of the fifteen years a zero use rate would be entered. While this is possible, the choice of the years to enter a zero use rate is arbitrary and can yield different results depending on the years chosen.

SEGMENT 6

The sources of benefits calculated from the technical parameters and costs entered in Segments 1 to 5 are:

1. increased combine usage,
2. increased sales of straight grades,
3. reduced weather damage,
4. reduced overdrying in fields,
5. reduced combine losses,
6. reduced weight loss from weathering,
7. decreased storage losses and,
8. decreased insect infestation.

If the same use rate pattern is assumed over the fifteen years, the benefits of each batch remain unchanged over the fifteen year lifetime of the NAD system. A brief explanation of the sources of benefits are provided below.

Increased Combine Usage. A ratio of the bin size to combine capacity is used to determine the additional hours of available combining time created. This ratio is then multiplied by the combine operating margin and the probability of increased combine use to determine the benefit value. For example, in Table 3 a total of $368.55 is the value imputed to one bin from extra combine usage.

Increased Sale of Straight Grades. A certain percentage of all grain harvested in a given year is taken off in either a tough or damp condition. In the absence of a NAD system this grain must be either custom dried or sold at a discount. A farmer who installs a NAD system and sells dry grain can be assumed to receive a benefit that is equal to the discount for the tough or damp grain. The value of increased sale of straight grades is determined by multiplying the quantity of grain dried by the proportion of grain harvested tough or damp by the appropriate discount rates for each of the damp and tough portion. In Table 3, the results indicate a benefit of $68.05 from barley, $98.45 from wheat and $96.90 from canola.

Reduced Weather Damage. As noted earlier, grain subjected to excess moisture after maturation may be reduced in grade and hence bring a lower return to the farmer. A NAD system can reduce these losses by extending the combine season and by increasing the available combining hours per day. The benefit attributed to reduced weather damage is derived by multiplying probability of grade loss by the discount rate for grade loss by the total quantity dried. In Table 3, the benefit arising from reduced weather damage was estimated at $204.

Reduced Overdrying in the Field. In the absence of a NAD system, a farmer must wait to begin combining until the grain has dried in the field. As a result some of the grain generally will be taken off at a lower moisture content than required thus reducing returns for the crop. This program assumes that if the farmer waits until the grain is dry before beginning combining, the average moisture content of the grain in the bin will be at least 1 percent below dry. It has been estimated that each one percent of moisture removed from the grain reduces the saleable weight of that grain by approximately 12 kilograms per tonne.

The total weight loss per batch if a NAD system had not been used is estimated by multiplying the number of tonnes by 0.012. This in turn is multiplied by that percent of grain which is not tough or damp and a likelihood factor indicating the probability of overdrying grain in the field. In this case, the likelihood of overdrying in the field is higher in the dry years. Likelihoods of 1.0, 0.5 and 0.25 were used for dry, average and wet years, respectively.

Reduced Combine Losses. The value of this benefit is found simply by multiplying the percent reduced combine losses believed to occur due to combining at higher moisture contents by the quantity of grain dried by the price of the grain. A reduced combine loss benefit of $130.68, $221.40 and $342.72 was estimated for barley, wheat and canola respectively in Table 3.

Reduced Weight Loss from Weathering. As indicated earlier, excess moisture after maturation can cause barley and wheat to lose weight and grade. Weight loss due to weathering multiplied by the grain price and quantity dried yields benefits of NAD arising from this source. Table 3 indicates a benefit of $44.87 for barley and $76.03 for wheat.

Decreased Storage Losses and Decreased Insect Infestation. The benefits attributed to prevention of these losses are calculated by multiplying the quantity of grain dried by grain price by the probability of either increased insect damage or storage loss.

Improved Treatment In Bin. This line is inserted to accommodate treatment for bug infestations if they occur. No attempt has been made to place a value on this factor.

SEGMENT 7

Segment 7 simply summarizes the annual cost, benefits and calculates the annual net benefit. An annual benefit/cost ratio (BCR) is also provided to show the relative magnitude of costs to benefits. This BCR, however, does not consider the capital cost of the NAD system consequently it is much higher than the BCR that includes the cost of capital. The annual BCR should not be used to assess the viability of a NAD system unless the capital expenditures of a NAD system have already been incurred and the user only wishes to determine if the annual benefits exceed the cost of operation.

SEGMENT 8

The opportunity cost of capital for this analysis was set at 5 percent. This was the discount rate used to determine the NPV and the BCR of the NAD system. A discount rate of 5 was chosen as it is believed to reflect the real opportunity cost of capital once inflation has been taken into account[19]. The user is able to enter his or her own opportunity cost of capital. The three evaluation criteria net present value, internal rate of return and benefit cost ration discussed earlier in the Methodology are calculated and displayed in this section.

[19]During July 1989, 9 to 10 percent interest rates were offered on term deposits. Subtracting 4 to 5 percent for inflation which has been typical recently yields an opportunity cost of approximately 5 percent.

IV. ANALYSIS OF RESULTS

To determine the operating costs of different NAD systems over a variety of conditions, over 300 computer simulations were run using the computer program "Grain Drying System Design" designed by Manitoba Agriculture. The information generated from the simulations was then entered in the Natural Air Drying Cost/Benefit program developed by the authors to determine the profitability of the same NAD systems under varying conditions. Annual costs and benefits over a fifteen year life span were aggregated and the profitability of NAD investment assessed on the basis of a set of evaluation criteria.

Benefits of Natural Air Drying

The benefits of natural air drying calculated in this study do not change with system variables such as in bin size, floor perforation, bin configuration, fan size or type, or decision variables such as harvest date, humidistat setting or place or moisture measurement. Only operating and investment costs are affected by these variables. Rather, benefits are affected by the value of the technical parameters, probabilities and prices chosen by the user which are independent of these system and decision variables used to determine operating costs. Consequently, the user's assumptions concerning the magnitude of these parameters in Segment 3 of Table 3 will affect the levels of the benefits. As the scenarios analyzed are combinations of system and decision variables holding the parameter values and prices which affect benefits constant, the total benefit per tonne by crop and location were unchanging. Given the value of parameters used, the estimated benefits are shown in Table 4.

TABLE 4. ESTIMATED PER TONNE BENEFIT OF EACH BATCH OF GRAIN DRIED, BY GRAIN, BY LOCATION.

Location	Barley	Wheat	Canola
	($/tonne)	($/tonne)	($/tonne)
Winnipeg	8.25	10.09	17.44
Dauphin	7.58	9.22	16.61
Brandon	7.56	9.22	16.61

As noted in Table 4, the benefits, however, do vary with location. The probability of a wet year, as defined in the methodology, is higher for Winnipeg. Consequently, the benefits of grain drying were higher for Winnipeg than Dauphin and Brandon which on average had less precipitation than Winnipeg.

The benefits also vary by crop as expected . The benefits of natural air drying were highest for canola followed by wheat then barley in all locations. Generally the higher the grain price, the greater the benefit per tonne. The greater benefit accorded canola is also attributed to a) the larger discount for tough grain and grade loss and b) higher base probability of storage loss. On a per batch basis, the benefit of drying wheat (Benefit $/tonne x quantity dried) exceeded barley as a larger quantity of wheat could be dried in the same bin.

The primary limitation of the study is that the estimated benefits do not change with the level of moisture in the grain to be dried. Lack of information concerning the rate of spoilage, loss of grade or insect infestation associated with different moisture levels in stored grain made it impossible to asses the relationship between benefits of natural air drying and moisture levels. Consequently, the study's estimated per tonne benefits of natural air drying within the same location (not costs) will be the same regardless of harvested moisture level.

Assuming that the benefits of NAD would increase with moisture level in stored grain, the net benefits estimated in the cost/benefit program would underestimate the profitability of natural air drying. The effect of varying moisture level on operating costs has already been determined by the MDA computer simulation program. As the benefits of drying wetter grain, such as quantity and quality losses within the bin has not been accounted, the estimated profitability of NAD systems will increase as moisture content increases.

Costs of Natural Air Drying

While the benefits per tonne of each grain dried do not vary with technical parameters specified or NAD system specifications, the same does not apply to the costs. The total costs of natural air drying vary with each NAD system and conditions imposed; the capital costs change with the size and type of bin and fan, and the operating costs vary with moisture, fan and bin size, fan type, and grain combinations dried. These costs ultimately affect the annual net benefits hence profitability of the NAD systems analyzed. The effects of varying conditions and NAD systems on natural air drying costs are addressed in the scenario results.

TABLE 5. SUMMARY OF NATURAL AIR DRYING SCENARIO RESULTS†

S#	FAN ID #	CROPS COMBIN	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NET BENEFIT ($)	NPV[9] ($)	IRR[9] (%)	BCR[9]
1	206	B/W/C	3000	18.8	14	5,500	936	4,220	15	1.19
	10 hp		5.5(dia)	18.5	21					
	CF		4.5(dep)	12.0	24					(very favourable)
2	206	W/C	3000	18.8	14	5,500	760	2,393	11	1.13
	10 hp		5.5(dia)	18.5	21					
	CF		4.5(dep)	12.0	24					(very favourable)
3	206	B/C	3000	18.8	14	5,500	716	1,927	10	1.12
	10 hp		5.5(dia)	18.5	21					
	CF		4.5(dep)	12.0	24					(very favourable)

†ASSUMPTIONS
1. Cereal flooring
2. August 20 harvest, barley
3. September 10, wheat
4. September 20, wheat
5. September 15, canola
6. Humidistat 60 percent moisture
7. Moisture measured at average
8. Negative sign denotes grain can't be dried in time allotted
9. Definitions on page 15, 16, 17

* Brandon
** Dauphin

Unfavourable	Favourable	Very Favourable
IRR < 5%	5% < IRR < 9%	IRR > 9%
NPV < 0	0 < NPV < $1,000	NPV > $1,000
B/C < 1.0	1.0 < B/C < 1.10	B/C > 1.10

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
4	206 10 hp CF	B/W	3000 5.5(dia) 4.5(dep)	18.8 18.5 12.0	14 21 24	5,500	439	(942)	2	.94 (unfavourable)
5	206 10 hp CF	C	3000 5.5(dia) 4.5(dep)	18.8 18.5 12.0	14 21 24	5,500	443	(906)	2	.93 (unfavourable)
6	206 10hp CF	B/W/C*	3000 5.5(dia) 4.5(dep)	18.8 18.5 12.0	15 22 25	5,500	769	2,483	11	1.11 (very favourable)
7	206 10hp CF	W/C*	3000 5.5(dia) 4.5(dep)	18.8 18.5 12.0	15 22 25	5,500	638	1,125	8	1.06 (favourable)
8	206 10hp CF	B/C*	3000 5.5(dia) 4.5(dep)	18.8 18.5 12.0	15 22 25	5,500	608	815	7	1.05 (favourable)
9	206 10hp CF	B/W/C**	3000 5.5(dia) 4.5(dep)	18.8 18.5 12.0	15 22 25	5,500	735	2,126	10	1.09 (very favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
10	206 10hp CF	W/C**	3000 5.5(dia) 4.5(dep)	18.8 18.5 12.0	15 22 25	5,500	587	593	7	1.03 (favourable)
11	206 10hp CF	B/C**	3000 5.5(dia) 4.5(dep)	18.8 18.5 12.0	15 22 25	5,500	579	513	6	1.03 (favourable)
12	206 10hp CF	B/W**	3000 5.5(dia) 4.5(dep)	18.8 18.5 12.0	15 22 25	5,500	349	(1874)	1	.87 (unfavourable)
13	206 10hp CF	B/W/C	3000 5.5(dia) 4.5(dep)	17.8 17.5 12.0	13 19 24	5,500	965	4,520	16	1.21 (very favourable)
14	206 10hp CF	B/W/C	3000 5.5(dia) 4.5(dep)	16.8 16.5 11.0	11 17 21	5,500	1,036	5,257	17	1.25 (very favourable)
15	206 10hp CF	B/W/C	3000 5.5(dia) 4.5(dep)	15.8 15.5 10.0	9 13 15	5,500	1,125	6182	19	1.30 (very favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
16	206 10hp CF	B/W/C	3000 5.5(dia) 4.5(dep)	16.8 16.5 12.0	11 17 24	5,500	1.005	4,935	16	1.23 (very favourable)
17	206 10hp CF	B/W/C*	3000 5.5(dia) 4.5(dep)	16.8 16.5 12.0	11 16 25	5,500	847	3,292	13	1.15 (very favourable)
18	206 10hp CF	B/W/C**	3000 5.5(dia) 4.5(dep)	16.8 16.5 12.0	12 17 25	5,500	777	2,561	11	1.12 (very favourable)
19	206 10hp CF	B/C	3000 4.8(dia) 6.1(dep)	18.8 18.5 12.0	16 -26 40	5,350	648	1,374	9	1.08 (favourable)
20	206 10hp CF	C	3000 4.8(dia) 6.1(dep)	18.8 18.5 12.0	16 -26 40	5,350	405	(1142)	2	.92 (unfavourable)
21	206 10hp CF	B/W	3000 4.8(dia) 6.1(dep)	18.8 18.5 12.0	16 -26 40	5,350	371	(1495)	1	.91 (unfavourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
22	206	B/W/C	3000	18.8	13	5,600	992	4696	16	1.22
	10hp		5.8(dia)	18.5	20					
	CF		3.9(dep)	12.0	22					(very favourable)
23	206	B/W[2,3]	3000	18.8	14	5,500	464	(683)	3	.95
	10hp		5.5(dia)	18.5	22					
	CF		4.5(dep)							(unfavourable)
24	206	B/W[2,3]*	3000	18.8	15	5,500	354	(1826)	0	.88
	10hp		5.5(dia)	18.5	22					
	CF		4.5(dep)							(unfavourable)
25	206	B/W[2,3]**	3000	18.8	15	5,500	348	(1884)	-1	.87
	10hp		5.5(dia)	18.5	23					
	CF		4.5(dep)							(unfavourable)
26	206	W	3000			5,500	318	(2197)	-2	.80
	10hp		5.5(dia)	16.5	17					
	CF		4.5(dia)							(unfavourable)
27	206	W[6]	3000			5,500				(cannot dry)
	10hp		5.5(dia)	16.5	-66					
	CF		4.5(dia)							

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
28	206 10hp CF	B/W*	3000 5.5(dia) 4.5(dia)	16.8 16.5	12 22	5,500	363	(1733)	0	.88 (unfavourable)
29	206 10hp CF	B[6]*	3000 5.5(dia) 4.5(dia)	16.8	-31	5,500	70	(4871)	-16	.52 (unfavourable)
30	907 5hp CF	B/W	3000 5.5(dia) 4.5(dia)	18.8 18.5 12.0	20 -33 -45	4,700	568	1,196	9	1.09 (favourable)
31	907 5hp CF	B/C[5]	3000 5.5(dia) 4.5(dia)	18.8 18.5 12.0	20 -33 36	4,700	852	4,148	16	1.30 (very favourable)
32	402 1.5hp axial	B	3000 5.5(dia) 4.5(dia)	18.8 18.5 12.0	-31 -58 -45	4,050	215	(1815)	3	.76 (unfavourable)
33	402 1.5hp axial	W	3000 5.5(dia) 4.5(dia)	18.8 18.5 12.0	-31 -58 -45	4,050	412	228	6	1.03 (favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
34	402 1.5hp axial	B/W	3000 5.5(dia) 4.5(dia)	16.8 18.5 12.0	23 -58 -45	4,050	675	2,961	14	1.26 (very favourable)
35	418 10hp CIF	B/W/C	3000 5.5(dia) 4.5(dia)	18.8 18.5 12.0	10 15 16	5,200	402	(1024)	2	.96 (unfavourable)
36	905 3hp CF	B/W	1200 4.2(dia) 3.1(dep)	18.8 18.5 12.0	10 16 -45	4,390	135	(2985)	8	.66 (unfavourable)
37	905 3hp CF	B/W	1200 4.2(dia) 3.1(dep)	16.8 16.5 12.0	8 12 -45	4,390	155	(2777)	7	.67 (unfavourable)
38	1502 1.5hp axial	B/W	1200 4.2(dia) 3.1(dep)	18.8 18.5 12.0	15 -26 35	3,640	234	(1215)	0	.86 (unfavourable)
39	1502 1.5hp axial	B/W/C	1200 4.2(dia) 3.1(dep)	16.8 16.5 12.0	12 20 35	3,640	349	(20)	5	1.00 (unfavourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
40	1502 1.5hp axial	B/C	1200 4.2(dia) 3.1(dep)	18.8 18.5 14.0	15 -26 -45	3,640	236	(1194)	0	.86 (unfavourable)
41	402 1.5hp axial	B/W/C	1200 4.2(dia) 3.1(dep)	18.8 18.5 12.0	14 24 43	3,640	333	(187)	4	.98 (unfavourable)
42	402 1.5hp axial	B/W/C	1200 4.2(dia) 3.1(dep)	16.8 16.5 12.0	11 18 43	3,640	353	(22)	5	1.00 (unfavourable)
43	402 1.5hp axial	B/C[5]	1200 4.2(dia) 3.1(dep)	18.8 18.5 12.0	14 24 32	3,640	216	(1402)	1	.84 (unfavourable)
44	417 5hp CIF	B/W/C	1500 4.2(dia) 3.9(dep)	18.8 18.5 12.0	10 16 19	4,320	240	(1824)	-2	.88 (unfavourable)
45	417 5hp CIF	B/W/C	1500 4.2(dia) 3.9(dep)	18.8 18.5 12.0	10 16 19	2,520	258	163	6	1.06 (favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
46	416 3hp CIF	B/W/C	1500 4.2(dia) 3.9(dep)	18.8 18.5 12.0	11 17 24	4,070	387	(48)	5	1.00 (unfavourable)
47	416 3hp CIF	B/W/C	1500 4.2(dia) 3.9(dep)	18.8 18.5 12.0	11 17 24	2,570	402	1,607	13	1.13 (very favourable)
48	416 3hp CIF	B/W/C	1500 4.2(dia) 3.9(dep)	18.8 18.5 12.0	11 17 24	1,670	456	3,065	27	1.29 (very favourable)
49	402 1.5hp axial	B/W	1500 4.2(dia) 3.9(dep)	18.8 18.5 12.0	20 -36 -45	3,720	204	(1598)	-2	.82 (unfavourable)
50	402 1.5hp axial	B/W	1500 4.2(dia) 3.9(dep)	18.8 18.5 12.0	20 -36 -45	2,220	219	58	5	1.01 (marginally favourable)
51	402 1.5hp axial	B/W	1500 4.2(dia) 3.9(dep)	18.8 18.5 12.0	20 -36 -45	1,670	247	892	12	1.14 (very favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
52	402 1.5hp axial	B/W	1500 4.2(dia) 3.9(dep)	16.8 16.5 12.0	15 -27 -45	3,720	228	(1348)	-1	.84 (unfavourable)
53	415 1.5hp CIF	B/W	1500 4.2(dia) 3.9(dep)	18.8 18.5 12.0	18 -30 -45	3,920	264	(1175)	0	.86 (unfavourable)
54	415 1.5hp CIF	B/W	1500 4.2(dia) 3.9(dep)	16.8 16.5 12.0	14 23 -45	3,920	271	(1102)	0	.87 (unfavourable)
55	206 10hp CF	B/W	5000 6.4(dia) 5.6(dep)	18.8 18.5 12.0	23 -40 -45	6,100	986	4,131	14	1.21 (very favourable)
56	206 10hp CF	B/C[5]	5000 6.4(dia) 5.6(dep)	18.8 18.5 12.0	23 -40 36	6,100	1,367	8,094	21	1.36 (very favourable)
57	417 5hp CIF	B/W	5000 6.4(dia) 5.6(dep)	18.8 18.5 12.0	24 -40 -45	5250	982	4,944	17	1.26 (very favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
58	417	B/C[5]	5000	18.8	24	5,250	1,355	8,815	25	1.41
	5hp		6.4(dia)							
	CIF		5.6(dep)	12.0	50					(very favourable)
59	206	C[5]	7500	18.8	-32	6,420	1,378	7,878	20	1.41
	10hp		7.3(dia)	18.5	-55					
	CF		5.6(dep)	12.0	49					(very favourable)
60	206	B	7500	18.8	-32	6,170	564	(320)	4	.97
	10hp		7.3(dia)	18.5	-55					
	CF		5.6(dep)	12.0	49					(unfavourable)
61	206	W	7500	18.8	-32	6,170	966	3,852	13	1.26
	10hp		7.3(dia)	18.5	-55					
	CF		5.6(dep)	12.0	49					(very favourable)
62	418	B/W	7500	18.8	19	6,120	1,035	4,620	15	1.17
	10hp		7.3(dia)	18.5	-30					
	CIF		5.6(dep)	12.0	31					(very favourable)
63	418	B/C	7500	18.8	19	6,120	1,436	8,789	22	1.29
	10hp		7.3(dia)	18.5	-30					
	CIF		5.6(dep)	12.0	31					(very favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
64	418	C	7500	18.8	19	6,120	838	2,578	11	1.10
	10hp		7.3(dia)	18.5	-30					
	CIF		5.6(dep)	12.0	31					(very favourable)
65	418	W	7500	18.8	19	5,870	678	1,163	8	1.07
	10hp		7.3(dia)	18.5	-30					
	CIF		5.6(dep)	12.0	31					(favourable)
66	418	B/C[5]	7500	18.8	19	6,120	1,284	7,211	20	1.22
	10hp		7.3(dia)							
	CIF		5.6(dep)	12.0	26					(very favourable)
67	418	B/W/C	7500	16.8	15	6,120	1,990	14,534	32	1.33
	10hp		7.3(dia)	16.5	23					
	CIF		5.6(dep)	12.0	31					(very favourable)
68	418	B/W[1]	7500	18.8	19	5,870	1,064	5,172	16	1.20
	10hp		7.3(dia)	18.5	30					
	CIF		5.6(dep)							(very favourable)
69	418	B/W/C[1,7]	7500	18.8	13	8,620	3,471	27,411	40	1.88
	10hp		7.3(dia)	18.5	19					
			5.6(dep)	12.0	17					(very favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
70	418 10hp CIF	B/W[1,7]	7500 7.3(dia) 5.6(dep)	18.8 18.5	13 19	8,370	1,969	12,068	22	1.63 (very favourable)
71	418 10hp CIF	B/C[1,7]	7500 7.3(dia) 5.6(dep)	18.8 12.0	13 17	8,620	2,454	16,851	28	1.74 (very favourable)
72	414 15hp CF	B/W	7500 7.3(dia) 5.6(dep)	18.8 18.5 12.0	20 -32 43	6,620	1,163	5,449	16	1.21 (very favourable)
73	414 15hp CF	B/C	7500 7.3(dia) 5.6(dep)	18.8 18.5 12.0	20 -32 43	6,620	1,891	13,012	28	1.49 (very favourable)
74	414 15hp CF	C	7500 7.3(dia) 5.6(dep)	18.8 18.5 12.0	20 -32 43	6,620	1,256	6,417	17	1.31 (very favourable)
75	414 15hp CF	W	7500 7.3(dia) 5.6(dep)	18.8 18.5 12.0	20 -32 43	6,370	769	1,607	9	1.09 (favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
76	414	B/C[5]	7500	18.8	20	6,620	1,695	10,978	25	1.38
	15hp		7.3(dia)	18.5	-32					
	CF		5.6(dep)	12.0	31					(very favourable)
77	206	B[1]	10000	18.8	-44	6,700	769	1,285	8	1.09
	10hp		8.2(dia)	18.5	-69					
	CF		5.6(dep)	12.0	-45					(favourable)
78	206	W[1]	10000	18.8	-44	6,700	1,443	8,277	20	1.53
	10hp		8.2(dia)	18.5	-69					
	CF		5.6(dep)	12.0	-45					(very favourable)
79	418	B/C	10000	18.8	23	6,700	2,108	15,176	31	1.44
	10hp		8.2(dia)	18.5	37					
	CIF		5.6(dep)	12.0	38					(very favourable)
80	418	B/W[1]	10000	18.8	23	6,400	1,553	9,716	23	1.33
	10hp		8.2(dia)	18.5	37					
	CIF		5.6(dep)	12.0	38					(very favourable)
81	418	B/W/C[7]	10000	18.8	16	9,300	4,468	37,081	48	2.01
	10hp		8.2(dia)	18.5	24					
	CIF		5.6(dep)	12.0	22					(very favourable)

S#	FAN ID #	COMBIN CROPS	BIN SIZE (bu)	MOISTURE (%)	DAYS	CAP INV ($)	NBENEFIT ($)	NPV ($)	IRR (%)	BCR
82	418 10hp CIF	B/C[7]	10000 8.2(dia) 5.6(dep)	18.8 18.5 12.0	16 24 22	9,300	3,159	23,498	34	1.89 (very favourable)
83	418 10hp CIF	B/W[1,7]	10000 8.2(dia) 5.6(dep)	18.8 18.5	16 24	9,000	2,565	17,623	28	1.80 (very favourable)
84	418 10hp CIF	B[1]	10000 8.2(dia) 5.6(dep)	18.8 18.5	23 37	6,400	595	(220)	4	.99 (unfavourable)
85	418 10hp CIF	C	10000 8.2(dia) 5.6(dep)	18.8 18.5 12.0	23 37 38	6,700	1,277	6,558	17	1.24 (very favourable)
86	418 10hp CIF	W[1]	10000 8.2(dia) 5.6(dep)	18.8 18.5	23 37	6,400	989	3,865	13	1.19 (very favourable)
87	418 10hp CIF	B/W[1,7]	7500 7.3(dia) 5.6(dep)	18.8 18.5	13 19	5,870	2,097	15,896	35	2.03 (very favourable)

Scenario Results

Location, bin size, bin configuration, fan choice, harvest date, place of moisture measurement, humidistat control and type of flooring are all factors which affect the costs and the profitability of natural air drying. An assessment of the effect of these factors on profitability are indicated in Table 5 in the various scenarios analyzed. For each scenario(S), choice of fan bin size, and moisture level is specified. The crop combination dried and the days required to dry each batch of grain are also indicated along with capital investment, net annual benefit, net present value, internal rate of return and benefit/cost ratio.

The harvest dates **for barley, wheat, and canola are assumed to be August 15, September 7 and October 1,** respectively. To dry three consecutive batches, each grain must be dried within 23, 24 and 45 days. If this could not be accomplished within the designated time frame, a negative sign preceeds the number of days required to dry the grain. The harvest dates do not imply that crops would be left in the field until these dates. Rather they were chosen as typical harvest dates assuming drying facilities are available for the three grains. Any date could be chosen for harvesting one, two or three grain combinations to be dried; the date depending on when harvesting is at an optimum stage. The only requirement is that each batch of grain be dried by the time the next grain harvested needs drying.

Unless otherwise stated a Winnipeg location, a canola floor, continuous fan operation and moisture measured at the top of the bin is assumed. If harvest date, location, flooring, or point of moisture measurement is altered, the change is indicated by a superscript and is documented in the Table. For example, scenario one (S1), the base scenario which other scenarios are compared, indicates that a NAD system consisting of a 3000 bushel bin of dimension 5.5 meters (diameter) by 4.5 meters (depth) matched with a 10 hp centrifugal fan can dry three batches, barley, wheat and canola (B/W/C) from 18.8, 18.5 and 12.0 percent moisture content respectively, down to 14.8, 14.5 and 9.0 percent. The capital expenditure on the system is $5,500 earning annual net benefits of $936. Over the 15 year lifetime, the system is estimated to return $4,220 in current dollars, ie., the NPV. An IRR of 15 percent and BCR of 1.19 were calculated indicating the investment is very favourable.

Scenarios one through 29 in Table 5 are ordered to indicate the effect of drying different grain combinations, alternative locations, moisture content, bin configurations, harvest dates, and humidistat control on the profitability of the base NAD system (3,000 bushel bin with 10 hp centrifugal fan). Different size and type of fans are combined with the 3,000 bushel bin in scenarios 30 to 35 inclusive, to determine the effect of fan choice on profitability of a NAD system utilizing 3,000 bushel bins. A discussion of the effect of each of these factors on profitability are presented in the same order. Scenarios 36 through 87 indicate the profitability of different NAD systems where bin size, and fans are varied. These scenarios are ordered according to bin size, beginning with a 1,200 bushel bin in scenario 36, continuing with the 1,500 bushel bin in scenarios 41 to 54, the 5,000 bushel bin in scenarios 55 to 58, 7,500 bushel bin scenario 59 to 76 and a 10,000 bushel bin scenario 76 to 86. The effect of fan type (ie., centrifugal, centrifugal in-line or axial), fan model, and fan size combinations with the various size of bins are tested in these scenario groups. The profitability of point of moisture measurement is also tested on the larger bins. This factor is particularly critical to the economics of natural air drying given the trend to larger on-farm storage bins. Generally, discussions of the profitability of the NAD systems indicated in scenarios 30 through 87 are ordered according to bin size, fan size, fan type, fan model and point of moisture measurement.

Base Scenario/Different Combinations

The base scenario (S1) consisting of a 3000 bushel bin, a 10 hp centrifugal fan, dryed three consecutive batches of 18.8, 18.5 and 12.0 percent moisture barley, wheat and canola respectively. Over the fifteen year lifetime, the system yielded a positive net present value (NPV) of $4,220, and earned an internal rate of return (IRR) of 15 percent. A BCR of 1.19 was calculated indicating the investment was favourable. The same NAD system drying combinations of wheat/canola (S2) and barley/canola (S3) yielded a positive net present value and an IRR greater than 5 percent, the assumed real opportunity cost of capital.
Both wheat/canola (S2) and barley/canola (S3) combinations yielded IRR exceeding 10 percent. However, a negative NPV and an IRR of 2 percent were estimated for the barley/wheat combination (S4). Similarly, drying a single batch of canola was estimated to be uneconomical (S5).

Given the level of capital investment in this NAD system, benefits generated by barley and wheat were not great enough to warrant investment in a NAD system. This implies that the capital costs of the NAD system must be reduced if lower valued grains are to be dried. The capital investment in a NAD system can be reduced either by purchasing smaller fans and bins, or employing existing farm power sources and fans. The feasibility of either of these alternatives is discussed in the section discussing fan size.

Benefits associated with drying canola were greater, consequently, combinations of canola with either barley or wheat were adequate to cover capital investment costs and operating expenses. Both barley/canola and wheat/canola combinations yielded IRR exceeding 10 percent (S2, S3).

Location

Table 6 lists the NPV and IRR for scenarios drying various combinations of grains in the Winnipeg, Dauphin and Brandon region. The NPV of drying barley/wheat/canola, wheat/canola and barley/canola combinations, was positive in all locations. However, the net present value (NPV) of natural air drying in Winnipeg (S1..S4) is almost double that of Brandon and three times that of Dauphin in the case of the wheat/canola combination (S6..S12). **The probability of a wet year in Winnipeg is higher, consequently, the benefits of a NAD system will be greater.** Second, the MDA simulation costs for drying canola are slightly lower in Winnipeg than in Brandon but almost eleven percent lower than in Dauphin. The higher canola drying costs in Dauphin are attributed to greater overdrying costs which quickly increase as the value of the grain increases.

The barley/wheat combination resulted in negative net present value in all three locations (S4, S12) but again the Winnipeg results were least unfavourable due to higher benefits. Dauphin total drying costs for the barley/wheat (S12) combination were slightly lower than Brandon and Winnipeg resulting in a slightly better net present value than Brandon but the differential in costs were not enough to offset the difference in benefits associated with drying in Winnipeg.

The relative ranking between locations attained for barley/wheat/canola combinations drying grain at moisture levels of 18.8, 18.5 and 12.0 percent remained the same when the moisture level was dropped to 16.8, and 16.5 for barley and wheat (S16..S18). For Winnipeg, Brandon and Dauphin respectively, the NPV increased $715, $809 and $435. Reduced drying costs contributed to the increase in the NPV. The relatively small increase in NPV in the Dauphin region is due to the higher canola overdrying costs.

Table 6. Evaluation Criteria Results for Natural Air Drying at Various Locations

Crop Combination	Winnipeg	Brandon	Dauphin
Barley/Wheat/Canola			
NPV$	4,220	2,483	2,126
IRR%	15	11	10
Wheat/Canola			
NPV$	2,393	1,125	593
IRR%	11	8	7
Barley/Canola			
NPV$	1,927	815	513
IRR%	10	7	6
Barley/Wheat			
NPV$	(942)		(1874)
IRR%	2		1

Changing harvest dates for barley and wheat to August 20 and September 10, had little affect on profitability. The NPV for the barley/wheat combination remained negative and the relative ranking between locations the same (S23..S25) as drying costs remained largely unchanged.

Moisture Content

Profitability of NAD at lower moisture contents were also analyzed. As the moisture content in grain declined (S13, S14, and S15), the expected profitability of the NAD systems increased. **For each percent drop in moisture content in the three grains, the NPV increased between $750 and $900 and the IRR increased between 1 and 2 percentage points.**

This result is attributed solely to lower operating costs. Lower moisture content required less electrical power to dry the grain, reducing annual operating costs. Capital costs which affect NPV remain unchanged and as data concerning the relationship between benefits and moisture content are nonexistent, the benefits are assumed unchanged. It is likely that with higher moisture content, spoilage would occur more quickly and be pervasive. This may affect marketing alternatives through reduced flexibility. Consequently, benefits of drying grain at higher moisture contents may be underestimated but we did not have the technical information to examine this important consideration. This would appear to be an issue that might rank high in further research priorities.

In larger bins, the effect of lower moisture content on profitability are more impressive. At moisture contents of 16.8 and 16.5 for barley and wheat respectively, a NAD system consisting of a 7,500 bushel bin and centrifugal in-line 10 hp fan can feasibly dry three grains consecutively. This raises the NPV of the same system capable of drying only barley/wheat

(S62) from $4,620 to $14,534 (S67) when barley/wheat/canola are dried and the IRR from 15 to 32 percent. The improved profitability is attributed to lower drying costs and the benefits accrued from drying canola.

Bin Configuration

The effect of different bin configurations on profitability are illustrated in scenarios 19 through 22. A shorter bin with a wider floor was compared to a taller narrower based bin. As the fan has to blow the drying front over a greater depth with a taller bin, drying time is longer. **Consequently, batches of barley, wheat, and canola could not be consecutively dried in the taller narrower bin using a 10 horsepower centrifugal fan.** Barley and canola could be dried within the designated time frame, but wheat could not be dried within 24 days to allow three batches of barley, wheat and canola to be dried. Using the wider shorter bin, wheat dried within 20 days, and barley and canola dried three and 18 days earlier.

A NPV of $4,696, BCR of 1.22 and IRR of 16 percent were estimated for the barley/wheat/canola combination (S22) using the shorter wider bin. As barley/wheat/canola could not be dried in the taller bin, barley/wheat, barley/canola and individual crops were analyzed to determine if natural air drying were profitable. Drying combinations of barley/wheat or canola alone proved unprofitable as the net benefit was not large enough to cover the capital cost of the fan, installation or the perforated flooring. However, a cost/benefit analysis of a barley/canola combination resulted in a NPV of $1,374, an IRR of 9 percent and a 1.08 BCR in the taller narrower based bin.

While the tonnes dried in the taller bin were slightly greater, resulting in longer drying time, the taller bins also increased overdrying costs. According to the MDA program which estimates moisture content over 10 layers, the moisture content fell as low as 1.7, 1.6 and 0.5 percent below dry in each of the barley, wheat and canola batches, respectively. Overdrying also occurred in the shorter wider bin but was not as prevalent falling 1.4, 1.1 and 0.2 percent below dry. **These results imply that mixing grain in the bin is a more important consideration in taller bins and may have a significant payoff in general.**

The lower capital cost associated with the taller bin and the higher benefit per batch due to larger grain volume, did not offset the higher drying costs. Consequently, the shorter wider bins result in greater profitability and flexibility.

Humidistat Control

The purpose of a humidistat is to control moisture intake into the bin through the fan as the bottom layer of grain rewets in damp weather. To control the intake of moisture, the humidistat can be set at various moisture settings which regulate fan operation. For example, a 60 percent humidistat setting indicates that the fan would only run when the moisture level in the outside air was under 60 percent humidity. With the exception of the scenarios undertaken to test the affect of humidistat control on profitability of natural air drying, 100 percent humidistat control was assumed in all the scenarios. This means that the fan was allowed to run continuously. Friesen and Huminicki explain that:

> grain which is located at the top of the bin is likely to spoil first since it is the last to dry. The more air that is delivered, the quicker the drying zone moves through the grain and the shorter the time that the top layer is at risk. The fan should be operated continuously until the drying zone moves through the top of the grain or the temperature drops low enough for safe storage. The bottom layer of grain overdries in dry weather and re-wets in damp weather. However, as rewetting occurs at the bottom, the drying zone continues to move upward. The rate of rewetting is slower than the drying rate so a few days of fan operation in wet weather will not seriously affect the overall drying rate.[1]

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[1]O.H. Friesen and D.N. Huminicki, Grain Aeration and Unheated Air Drying. Manitoba Agriculture, Agdex 732-1, June 1986, p. 7.

Based on Manitoba Agriculture's computer simulation, it took 17 days to dry a 3000 bushel bin of 16.5 moisture wheat, with a 10 hp centrifuagal fan when the fan was running continuously (S26). The same scenario with a 60 percent humidistat setting could not dry wheat within the 66 days to the November 15 deadline (S27).

Using the same bin and fan combination, Scenarios 28 and 29 indicate the effect of humidistat control on 16.8 percent moisture barley in Brandon. With 60 percent humidistat control it took 31 days to dry barley down to 14.8 percent as opposed to 12 days when the fan was left running. Restricting fan operation also eliminated the possibility of two batch drying therefore reducing profitability. Although both scenarios were uneconomical, the relative effect on NPV can still be observed as the NPV dropped from negative $1,733 to negative $4,871 when 60 percent humidistat control was exercised.

Bin Size

Increasing the bin size from 3,000 bushels to 5,000 bushels reduced drying flexibility. Barley/wheat/canola, barley/canola and wheat/canola combinations could not be dried within the time frame allocated. However, drying barley/wheat with this combination of bin and fan (S55) was more profitable than the 3,000 bushel bin (S4). The larger volume dried raised total benefits thus offsetting the initial investment in the system. **Increasing the size of the bin raised the NPV from negative $942 to $4131 and IRR from 2 percent to 14 percent.**

The profitability of this same system could be further increased if canola were harvested earlier (S56). An earlier canola harvest date, September 15, enabled a barley/canola combination to be dried. This increased profitability as the annual net benefit of drying canola is greater. NPV increased $3964, raising NPV to $8094 and IRR to 21 percent from 14 percent.

Continuing with the same size fan, moisture conditions and location, but changing to a larger 7500 bushel bin, only individual grains could be dried (S59, S60, S61). Drying canola early, (S59), resulted in an estimated NPV of $7,878 and IRR of 20 percent. However, if only wheat were dried, profitability declined with NPV falling to $3,852, a drop of $4,042 in present value terms over the projected life time of the system. While this particular NAD system was less profitable, **the results were still favourable.** Benefits associated with barley were too low to cover the capital cost of the system yielding a NPV of negative $320.

Going to a 10,000 bushel size bin, the 10 hp centrifugal fan could still dry either barley or wheat individually but not canola even at an earlier harvest date. Drying wheat (S78) resulted in an estimated NPV of $8,277 and 20 percent IRR. The profitability of drying barley was much lower with a NPV of $1,285 and IRR of 8 percent (S77).

Note that the profitability of drying barley in a 10,000 bushel bin (S77) is greater than that using a 7,500 bushel bin (S60). This is due to 1) lower investment cost per tonne dried, 2) improved fan efficiency which reduced total drying costs per tonne, and 3) lower operating costs; with the larger bin, repair, maintenance and insurance costs per tonne were less as the capital cost upon which insurance and maintenance expenses are based did not increase at a constant rate per tonne. Table 7 lists the drying costs and total operating expenses per tonne for barley in 7,500 and 10,000 bushel bin.

TABLE 7. OPERATING EXPENSES PER TONNE OF BARLEY FOR 7,500 AND 10,000 BUSHEL BINS

	7,500 bu Bin	10,000 bu Bin
Tonnes dried	145	183
Drying Costs per tonne	$2.32	$2.17
Operating Costs per tonne	$4.32	$4.04

Fan Size

The capability and profitability of **using smaller fans on a 3000 bushel bin**, assuming a Winnipeg location, was also tested. As indicated in scenario 30, a five horsepower centrifugal fan could not dry wheat and canola within the time frame allotted for three batch drying. **The only feasible combination which would maximize possible returns was a barley/wheat combination yielding a NPV of $1,196 and an IRR of 9 percent.** It is important to note that this combination is not only feasible but profitable. **Under the same conditions using a 10 horsepower centrifugal fan (S4), natural air drying is not profitable** as a negative NPV was estimated ($942). The larger fan is not only more expensive, thereby increasing the capital cost of investment but requires more power to run increasing the cost of drying. Only when three batches of grain (one each of barley, wheat and canola) are to be dried, is the 10 hp centrifugal fan with the 3000 bushel bin more profitable (S1).[17] **This illustrates the importance of matching the right choice of fan with the grain to be dried.**

The profitability of using a five hp fan is further increased if canola is harvested Sept 15 at 12 percent moisture content (S31). A barley/canola drying combination is then feasible and the NPV increases to $4,148 with an IRR of 16 percent.

Smaller fans more often used to aerate or cool grain were also tested. A 1.5 hp axial fan (S32) was unable to dry any of the grains in a 3000 bushel bin in the designated time frame which would permit three consecutive batches to be dried. However, such a system could dry barley or wheat alone by the November 15 deadline (S32, S33). While technically feasible, the estimated NPV for drying barley was negative and the NPV for wheat positive at $228 (S32, S33). The level of benefits associated with these grain combinations in this particular NAD system is too low to cover the capital investment. If barley moisture content were lowered to 16.8 percent, a barley/wheat combination could then be consecutively dried increasing the level of benefits consequently the profitability (S34). A NPV of $2,961, 16 IRR and 1.21 BCR were estimated for this scenario. **The smaller fans often associated with aeration objectives can, under limited circumstances, pay off for natural air drying purposes.**

[17] If the farmer is certain that he/she would dry only barley/wheat combinations then the NAD system with the smaller fan is more profitable. Conversely, if he believes that three combinations can always be dried, the larger NAD system is more profitable. More realistically the truth is somewhere in between; in some years canola would be dried and not in others. In this situation the farmer could enter a use rate of zero for canola for some years and determine the profitability of the system. Again this approach is arbitrary as the profitability will depend on which years a zero use rate was entered. If the user believes that canola would not be dried three out of every 15 years, this problem might be circumvented if the three years which a zero use rate was to be entered were chosen by a true random process.

Further examples of the affect of fan size on the profitability of air drying are shown in scenarios S44 and S46 using a 1500 bushel bin. A 5 hp centrifugal in-line fan (S44) is technically able to dry three consecutive batches of grain but is economically infeasible as it has a NPV of negative $1,824 and a negative two percent IRR. Similarly, a 3 hp centrifugal in-line fan (S46) is able to dry three batches of grain but is borderline economically infeasible with a NPV of negative $48. The lower purchase cost of the 3 hp centrifugal in-line fan and lower total drying costs, as overdrying costs are lower, improved economic performance of the smaller system.

As indicated in Chapter three discussing the cost/benefit spreadsheet, it is assumed that the farmer does not have electrical power at the bin sites and must invest in the installation. If power is already available at the bin sites, the profitability of drying down a single batch of grain increases, in some cases significantly . For example, assuming power to the bin site was previously present and required only minor electrical adjustments[18], the economic feasibility of drying three batches of grain in a 1,500 bushel bin with a five hp fan becomes borderline economically feasible, the NPV increasing from negative $1824 (S44) to $163, (S45). In the case of the 3 hp centrifugal in-line fan, the NPV increased from negative $48 (S46) to $1607 with an IRR of 13 percent (S47).

If power to the bin site were already installed, a 1.5 hp axial fan which was previously mentioned to be uneconomical when matched with a 3,000 bushel bin (S32), is economical when matched with a 1,500 bushel bin (S50). Although this NAD system could not dry three consecutive batches of grain, in economic terms it performed as well drying barley/wheat as a 5 hp fan drying barley/wheat/canola (S44). Scenario 50 indicates a positive NPV of $58

[18] Assumed the only additional power investment would be $200 for power cords.

and IRR of 5 percent. Compared to the NAD system using a 5 hp fan, lower drying costs and capital expenditure on the 1.5 hp axial fan were responsible for the system's relative performance. If the cost of the fan was further dropped as a capital expenditure, assuming an axial fan currently used on the farm for aeration could be incorporated into a NAD system, the NPV increased to $892 with an IRR of 12 percent, (S51). Similarly if purchase costs are less than used in the study, benefits will increase.

Looking at larger 5,000 bushel bins, the importance of matching fan and bin size are again illustrated. Only a barley/wheat combination could be dried with the 10 hp centrifugal fan. Profitability of drying this sequence of grains could be increased if a 5 hp centrifugal in-line fan were used instead (S55, S57). While total operating costs of the two fans were almost identical, (higher insurance and maintenance costs associated with the 10 hp centrifugal fan were offset by slightly lower drying costs), the capital investment in the NAD system using the centrifugal in-line fan was approximately $850 lower. Consequently, the NPV of the NAD system incorporating the smaller fan was estimated at $4,944, $813 higher than that estimated for the centrifugal fan ($4,131). Going to a barley/canola sequence where canola is harvested September 15, improved the profitability of both systems (S56, 58). The relative spread in NPV remained nearly the same at $720 as NPV increased to $8,815 and $8,094 for the centrifugal in-line and centrifugal fan scenarios, respectively.

A smaller horsepower fan that is physically capable of drying the same combinations of grain as larger fans does not guarantee that the NAD system using the smaller fan is more profitable. Scenarios 62 through 66 and 72 through 76 list the results of two NAD systems where the larger horsepower fan is more economical. The first five scenarios (S62..S66) combine a 10 hp centrifugal in-line fan with 7,500 bushel bin and the second group of scenarios (S72..S76) use a 15 hp centrifugal fan. While all fan/bin/grain combinations were profitable, the NAD system using the fifteen hp fan was more profitable, particularly for those combinations drying canola, as the total drying costs associated with the 10 hp fan were much higher. A comparison of the drying and overdrying costs of the two fans for the three grains are listed in Table 8. The higher initial expenditure of $500 associated with the purchase of the 15 hp fan would be paid off within one year by any two grain combination which included canola or within two years if only one batch of canola (and no other grain) were dried annually.

Table 8. DRYING AND OVERDRYING COST COMPARISON BETWEEN TWO FANS[1]

Grain	Centrifugal In-line Fan 10 hp	Centrifugal Fan 15 hp
	$	$
Barley		
Drying Costs	211	284
Overdrying Costs	307	192
Total drying Costs	518	476
Wheat		
Drying Costs	345	462
Overdrying Costs	520	292
Total drying Costs	865	754
Canola		
Drying Costs	364	581
Overdrying Costs	1,109	454
Total drying Costs	1,473	1,035

[1] Fans coupled with a 7,500 bushel bin.

Fan Type

Changing the type of fan while maintaining the same horsepower can alter profitability of natural air drying. For instance, the evaluation criteria for determining the profitability of two 3,000 bushel NAD systems drying balrey/wheat/canola combinations using a 10 hp centrifugal fan, the other a 10 hp centrifugal in-line fan are listed in scenarios 1 and 35. The results highlight the importance of matching fan type and bin size with respect to the batches to be dried. Overall the NAD system using the centrifugal in-line fan with a 3000 bushel bin (S35) was uneconomical (NPV - $1024) whereas the system using the centrifugal fan proved profitable (NPV $4,220). IRR were 2 and 15 percent, respectively. Higher operating expenses resulting from higher overdrying costs outweighed the initial investment advantage of the less expensive centrifugal in-line fan. The annual net benefits of the system using the centrifugal fan were estimated at $932 compared to $418 for the centrifugal in-line fan.

Turning to a smaller fan and bin combination, the effect of fan type on profitability is illustrated in scenarios 49 and 53. In these two scenarios, 1.5 hp fans are matched with a 1500 bushel bin. Scenario 49 uses a 1.5 hp axial fan whereas scenario 53 utilizes a centrifugal in-line 1.5 hp fan. In both systems, the specified NAD systems were uneconomical. However, the relative contribution of the different fans to profitability can still be assessed. The capital investment in the axial fan is less than the centrifugal in-line fan but the drying costs associated with the centrifugal in-line fan were lower. The end result were NPV of -$1598 for the axial fan model and -$1175 for the centrifugal in-line fan. Lowering the moisture level for barley and wheat improved the NPV slightly for both systems but the same relative relationship remained and both continued to be uneconomical (S52, S54).

The results of the cost/benefit analysis indicate that the effect of different fan types on profitability of larger NAD systems depended on the grain combinations to be dried. Two ten horsepower fans, a centrifugal and a centrifugal in-line fan were matched with 7,500 and 10,000 bushel bins. As indicated previously in the discussion on bin size, the centrifugal fan was able to dry only a single batch of either barley or wheat (S60, S61 for the 7,500 bushel bin and S77, S78 for the 10,000 bushel bin) and 12 percent moisture canola if harvested by September 15 (S59). When compared to the centrifugal in-line fan drying single batches of either wheat or barley (S65, S84,and S86), the NAD system using the centrifugal fan was more economical due to the higher drying costs associated with the centrifugal in-line model. NPV of $1,285 and $8,277 were estimated for a 10,000 bushel/10 hp centrifugal fan NAD system drying either barley or wheat, respectively. The same system using a centrifugal in-line fan resulted in estimated NPV of -$220 and $3,865 for barley and wheat individually. However, the centrifugal in-line fan is able to dry the grain more quickly, enabling the producer to dry two batches. Both barley/wheat and barley/canola combinations can be dried with the centrifugal in-line fan in both the 7,500 and 10,000 bushel bins (S62, S63 for the 7,500 and S79 and S80 for the 10,000 bushel bin). The ability to dry two batches resulted in estimated NPV for the 10,000 bushel bin of $15,176 and $9,716 for the barley/canola and barley/wheat combinations, respectively. Clearly, if two batches of grain could be dried, barley/wheat or barley/canola, the system utilizing the centrifugal in-line fan under the conditions specified would be more economical.

Fan Model

The results of two different model 1.5 hp axial fans on a 1200 bushel bin are illustrated in scenarios 38 through 43. Both fans were 18 inches in diameter but varied slightly in litres per second output at different levels of static pressure. They were identified in the Manitoba Agriculture Fan Test Results publication as model 1502 and 402. The 1502 model fan took 26 days to dry wheat at 18.5 percent moisture therefore three batch drying was infeasible in the time frame allotted. The 402 model fan took only 24 days to dry wheat and dried barley quicker. Conversely, the 1502 model dried 12 percent moisture canola more quickly, drying within 35 days as opposed to 43 days for the 402. This serves to show that relative performance between fans on a single grain cannot be directly applied to other grains.

Neither fan resulted in a profitable investment although the loss with the 402 model drying barley/wheat/canola was less than the 1502 model drying barley/wheat. NPV of negative $187 and negative $1215 (S41, S38) were estimated, respectively. The poorer economic performance of the 1502 is attributed to greater overdrying costs.

Cereal Flooring

A cereal floor has approximately 13 percent perforation coverage and a canola floor 11 percent. Beyond an 8 percent level, perforation coverage has no affect on static pressure[19]. Consequently, the drying time and drying cost of either wheat or barley were unaffected by the type of floor. Assuming that canola would not be dried at any time, the profitability of a NAD system would be enhanced by a cereal floor as the capital investment in a cereal floor is two to three hundred dollars less than that of a canola floor in the larger NAD systems.

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[19] Information attained from agricultural engineers.

A comparison of scenarios 62 and 68 indicate that the NPV of a NAD system drying barley/wheat is increased by approximately $500 when a cereal floor is used. This is due to the lower capital investment in a cereal floor and the slight difference in insurance and maintenance costs associated with the capital investment.

Unless the producer knows with certainty that he will never require drying facilities for canola, incorporating a canola floor is more profitable in the long run. The difference in capital costs of approximately $250 can be paid in one year. Using a NAD system consisting of a 7,500 bushel bin and a 10 hp centrifugal in-line fan, the annual benefits of drying barley/canola (S63) exceed barley/wheat (S68) by an estimated $370.

Point of Moisture Measurement

All the scenarios discussed thus far have assumed that drying is completed when the moisture content in the top layer of the bin reaches the specified dry level. However, the MDA computer program does allow the user to choose average bin moisture content as an alternative for determining drying completion. Currently, no practical means exist to determine the moisture level over the ten layers as identified in the MDA program and determine the average bin moisture. Consequently, measurement at the top of the bin was chosen as a more realistic representation of on-farm practices.

Although perhaps more realistic, drying completion determined by moisture content at the top layer results in overdrying and increases operating expenses. Also grain drying time is longer and reduces drying flexibility. If drying completion could be determined by average bin moisture content, the profitability of NAD systems would be enhanced.

The profitability of NAD systems, consisting of either 7,500 and 10,000 bushel bins and a 10 hp centrifugal in-line fan drying grain to an average moisture content, were estimated in scenarios 69, 70, 71 and 81, 82, and 83. To reflect the problem of different moisture levels throughout the bin and improve the feasibility of drying to an average moisture content, double stirring devices were added to the NAD systems. The assumption was made that the moisture content at the top of the bin where measurement is usually taken, would be representative of the moisture level throughout the bin if stirrers were used[20]. The capital investment costs of double stirrers for 7,500 and 10,000 bushel bins were priced at $2,500 and $2,600, respectively. While the operating costs of stirring devices are unknown, it is possible that drying time would be enhanced reducing total fan drying costs below those estimated by the MDA program, offsetting the operating cost of stirring devices. A comparison of the NPV and IRR of these two NAD systems by point of moisture measurement is illustrated in Table 9.

The difference in net benefit between average and top point of moisture measurement is due to significantly lower operating costs. There were no overdrying expenses associated with either barley or wheat drying, and canola overdrying expenses were approximately halved. Drying expenses were also lower across the three grains when the grain was dried to average bin moisture. Table 10 lists the drying and overdrying expenses associated with the three grains when termination of drying is designated by top and average bin moisture content. **Generally, the NPV doubled to tripled when grain was dried to its average moisture content.**

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[20] When determining drying completion on the basis of average moisture content, the MDA computer program assumes the grain layers in the bin are undisturbed. The average moisture content is based on the moisture content at each of the ten layers. While the additions of stirring devices would disturb the drying front, thus the rain layers, it is possible that grain drying may occur more quickly than the MDA simulations indicate. In these scenarios, it is assumed that the drying time would remain the same when stirring devices were added to the NAD system, consequently, fan operating costs also would be unchanged from that indicated by the MDA simulation for drying to average moisture content.

TABLE 9. PROFITABILITY OF NAD SYSTEMS BASED ON POINT OF MOISTURE CONTENT MEASUREMENT

Point of Measurement	Top	Avg	Top	Avg	Top	Avg
Grain Combination	B/W	B/W	B/C	B/C	B/W/C	B/W/C
7,500 bushel bin/ 10 hp in-line centrifugal fan						
Net Ben.($)	1,035	1,969	1,436	2,453	*	3,471
NPV ($)	4,620	12,068	8,789	16,851	*	27,411
IRR (%)	15	22	22	28	*	40
10,000 bushel bin/ 10 hp in-line centrifugal fan						
Net Ben ($)	1,553	2,565	2,108	3,160	*	4,468
NPV ($)	9,716	17,623	15,176	23,498	*	37,081
IRR (%)	23	28	31	34	*	48

Notes: * technically infeasible, it would not dry
B=barley, W=wheat, C=canola

TABLE 10. DRYING AND OVERDRYING EXPENSES ASSOCIATED WITH POINT OF MOISTURE MEASUREMENT FOR BARLEY, WHEAT AND CANOLA

	7,500 bus. bin		10,000 bus. bin	
Measurement Point	Top $	Avg $	Top $	Avg $
Barley				
Drying Cost	211	139	244	162
Overdrying Exp	307	-	339	-
Total Drying Cost	518	139	583	162
Wheat				
Drying Cost	345	214	406	259
Overdrying Exp.	520	-	574	-
Total Drying Cost	865	214	980	259
Canola				
Drying Cost	364	203	451	263
Overdrying Exp.	1,109	504	1,209	636
Total Drying Cost	1,473	707	1,660	899

The results indicate a payoff in terms of both drying time and overdrying costs to some form of mixing the grain. It is possible for a farmer to rotate the grain manually (load/unload a truck). If the bin is part of a mechanized grain handling system, it can be rotated easily and cheaply. It is estimated in scenario 87 that the payoff to this activity, assuming no additional costs, is an increase in NPV of $3,800 from $12,070 (S70) to $15,900 (S87) or an increase in the IRR from 22 to 35 percent.

Sensitivity Analysis

The profitability results associated with each scenario listed in Table 5 are dependent on the values of the technical parameters chosen. If these values are changed, the profitability of the NAD systems analyzed will subsequently change. While this is to be expected, it is imperative that the user know how sensitive the results are to changes in the parameters. For many of the parameters entered in the cost/benefit tableau, the user would be entering his best guess based on recollection of past conditions. Consequently, it is useful to know how sensitive the final profitability assessment is to the parameter values to reduce the risk of making an erroneous decision based on less than perfect information.

The effect of parameter value changes on the profitability of the system can be deduced to some extent by analyzing the sources of benefits for each grain dried and comparing the size of the benefits. For instance, increased combine usage is the largest single source of benefit for each of the three grains dried. Consequently, one may deduce that variations in the value of at least one of the combine parameters should have a substantial effect on profitability.

Alternatively, the effect of varying parameter values on the profitability of NAD systems may be determined using sensitivity analysis. This procedure essentially involves changing parameter values and observing how net present value, internal rate of return and benefit/cost ratio changed over a range of values for that parameter. For example in the study, the combine operating margin was set at $70/hr. Using sensitivity analysis, a range of combine operating margins of $60 to $90 is set, with combine operating margins of $5 increments tested to determine the effect on profitability. The resulting evaluation criteria for each value the combine operating margin assumes indicates how sensitive the profitability assessment is to the parameter value chosen.

Sensitivity analyses were performed on 14 parameters, however, more than 14 analyses were done on each scenario as often the parameter value varies with the grain dried. For instance, the discount for grade loss varies with barley, canola and wheat whereas the combine operating margin is assumed to be invariant of the grain harvested and dried. The parameters tested by sensitivity analysis were:

1. Grain price - wheat, barley and canola where applicable.
2. Combine operating margin.
3. Combine capacity.
4. Base probability of combine use.
5. Discount for tough grain- wheat, barley and canola where applicable.
6. Discount for damp grain- wheat and barley where applicable.
7. Base probability of harvest tough/damp.
8. Base probability of grade loss.
9. Discount for grade loss- wheat, barley and canola where applicable.
10. Reduced combine losses.
11. Base weight loss due to weather.
12. Excess handling costs.
13. Base probability of storage loss -wheat, barley and canola where applicable.
14. Base probability of storage loss.

In the sensitivity analyses undertaken in this study only one parameter value was changed at any one time. While it is feasible to change more than one parameter at a time, 87×10^9 number of combinations are possible with fourteen parameters.

Sensitivity analyses were performed on scenarios 1 and 33. Scenario 1 is the base scenario which consists of a 3,000 bushel bin matched with a 10 hp centrifugal fan, drying one batch each of barley, wheat and canola in Winnipeg. The NAD system in scenario 33 consists of a 3,000 bushel bin matched with a 1.5 hp axial fan drying one batch of wheat. Scenario 33 was chosen as a few distributors of farm storage equipment indicated that some farmers would prefer to dry only one batch per bin rather than transfer the grain from the NAD bin to another bin. The bin/fan combination in scenario 33 jointly minimized the capital cost of investment and maximized profitability of the NAD system assuming one batch drying in a 3,000 bushel bin.

The sensitivity analyses on scenarios 1 and 33 are indicated in the tables in Appendices 2 and 3, respectively. For each parameter, and where applicable for each grain of that parameter, a table of the NPV, IRR and BCR over the range of values indicated was formed. The parameter values were set to range a minimum of fifty percent over and under the range of values set in the study, therefore reference to percent incremental changes are based on the initial study values chosen. A detailed breakdown of the results is not discussed. The reader is referred to the appendices and the respective tables if they wish to review the results of the sensitivity analysis in more detail than that which is to follow.

Scenario 1 - Base Scenario

In none of the sensitivity tests did the base NAD system become uneconomical when only one parameter estimate was changed. The affect of a change in parameter values on the extent of profitability, however, did vary considerably between parameters. The effect of grain price changes on the profitability of NAD systems is indicated in tables A2.1, A2.2 and A2.3. A change in the price of canola had the biggest impact on profitability, followed by wheat and barley. This is to be expected as the estimated annual net benefits for barley, wheat and canola in this scenario were \$1.76, \$3.17 and \$8.24/tonne. A 9, 7, and 3.5 percent change in the three grains prices (\$10 increments) resulted in 6.5, 8.0 and 8.0 percent changes in the NPV of the base NAD system for each grain.

Tables A2.4, A2.5 and A2.6 list the results of varying combine operating margin, combine capacity and base probability of increased combine use. Changes in the combine operating margin had the least effect on profitability of the three combine parameters. A 20 percent increase in combine operating margin resulted in approximately a 6 percent increase in NPV. The effect of incremental changes in the base probability of increased combine use and combine operating capacity were similar. A 20 percent increase in the base probability of combine use from 0.25 to 0.30 percent resulted in an 18 percent increase in NPV through increased benefits associated with increased combine usage. Conversely, a 20 percent increase in combine capacity from 10 mt/hr to 12 mt/hr reduced NPV by 20 percent. The benefits associated with combine usage were based on the number of additional combining hours created. Given the size of batches dried in scenario one, a greater number of additional combine hours would be created if the farmer owned a smaller combine as it would have taken him longer to take off the same crop volume. The profitability of the NAD system when a smaller combine is used may be overstated, however, as single parameter sensitivity analysis does not change the operating margin of the combine which may change with combine size.

The discount for tough wheat and canola and the discount for wheat and canola grade loss had a relatively small effect on profitability, (Tables A2.7, A2.8, A2.12 and A2.13). For every dollar discount of tough wheat and canola, NPV decreased 2.8 and 1.0 percent, respectively. The larger dollar effect attributed to wheat is due to the fact that the one dollar discount is 14 percent of the value used in the study whereas a one dollar change in the discount for canola accounts for only an 8 percent change from the value used in the study. Consequently, changing the discount rate for wheat by one dollar resulted in a greater percentage change in the wheat parameter. The different effect of an equal change in the discount of one dollar suggests that care must be used in comparing the sensitivities of parameters.

The base proportion of grain harvested tough or damp did not have a large effect on profitability, (Tables A2.9 and A2.10). Changing the base proportion for barley and wheat from 0.15 to 0.10 (33 percent change in the parameter value) and canola from 0.10 to 0.05 (50 percent change) resulted in NPV varying by 12 and 10 percent, respectively. Changing the base probability of grade loss for barley and wheat, Table A2.11, yielded a 14 percent change in NPV when the base probability was changed 20 percent from 0.25 to 0.20.

Next to canola prices, changing the level of reduced combine losses had the largest effect on profitability, (Table A2.14). Adjusting the combine loss from 1.8 to 2.0 percent (an 11 percent change in the parameter value) resulted in NPV increasing by 20 percent. If the reduction in combine losses were raised to 4.5 percent, the NPV would increase to $15,015. As indicated in the methodology, the study parameters values were chosen so as not to favour natural air drying. Given a variety of circumstances the system might be subjected to, this was done to reduce the risk of showing profitability when the investment was not in fact profitable.[22]

[22]Circumstances where the technical parameters would be pushed to their limit. For instance situations where many of the technical factors affecting cost are at their highest resulting in high costs simultaneously with technical factors affecting benefits which may be at their lowest therefore minimizing benefits. Together this situation would crowd net benefits from both the cost and benefit side reducing the likelihood profitability.

Changes in NPV resulting from changes in the barley and wheat base weight loss due to weathering were small, (Table A2.15.) A 16 percent adjustment in the value of the base weight loss from 3.0 to 2.5 percent resulted in NPV decreasing 5 percent. Similarly, an increase in base weight loss to 3.5 percent increased the estimated NPV by 5 percent.

The effect of changing excess handling costs were also small in comparison to some of the other parameters. A 33 percent increase in handling costs, from $1.50 to $2.00/mt decreased NPV by only 8 percent. Again, between-parameter comparisons concerning profitability are cautioned. For example, if a producer valued his labour in shifting grain from the NAD bin to the next bin at $3.00/mt, a $.50 change in the parameter value to $3.5/mt constitutes a 16 percent change in the parameter value yet causes the same 8 percent decrease in NPV. In terms of percent changes in the parameter level, the effect of adjustments in excess handling on profitability would be greater in this second example - NPV decreasing 0.5 of a percent for every one percent increase in excess handling cost per tonne as opposed to approximately 0.25 of a percent per tonne when excess handling cost is valued initially at $1.50/mt. However, in absolute terms, variations of $0.5/mt for handling result in an 8 percent change in NPV regardless of the initial study level. The only problem with this approach is it is difficult to compare parameter effects when some parameters involve dollar units such as price and discounts, and others percentile units such as base probabilities and reduced combine losses.

Tables A2.17 and A2.18 list the effect of changes in storage losses and insect damage on NPV. The effects are identical in this study as both were given the same base probabilities and subjected to the same weather probabilities, and have identical formulas in calculating the level of benefits associated with it. Each one quarter percent change in the probability of storage loss or insect damage (which is a 50 percent change in the parameter value) caused NPV to vary by 12 percent.

Unlike many of the other parameters which caused equal changes in NPV with incremental changes in the parameter value, the effect of adjustments in the opportunity cost of capital varied with the level of the opportunity cost. As the opportunity cost was lowered, the NPV increased at an increasing rate. Conversely, as the opportunity cost increased the NPV decreased at a decreasing rate. The reason for this has to do with the magnitude of the NPV of the stream of annual net benefits relative to the size of the capital cost which is fixed and already in PV terms. As the opportunity cost decreases (rate of interest), the PV of the stream of net benefits increases. Consequently, the NPV of investment is larger. Conversely as the interest rate increases, the present worth of the annual benefits declines resulting in a smaller NPV.

A one percentage point change in the opportunity cost from 5 percent to either 4 or 6 percent caused NPV to change by 16 and 15 percent, respectively. In this scenario, an IRR or opportunity cost of 15 percent is required to reduce the NPV of the base NAD system to zero.

The relative importance of the technical parameters to the base scenario results are clarified in Table 11. For each technical parameter, a parameter elasticity with respect to present value is estimated. The elasticities indicate the percent change in NPV arising from

TABLE 11. PARAMETER ELASTICITIES WITH RESPECT TO NET PRESENT VALUE, SCENARIO 1

PARAMETER	ELASTICITY	RANK
Barley Price	.72	6
Wheat Price	1.22	3
Canola	2.31	1
Combine Op. Margin	.28	10
Combine Capacity	.73-1.10	4
B.P. Increased Combine Use*	.91	5
Discount Tough Wheat	.20	14
Discount Tough Canola	.24	11
Tough/Damp Barley and Wheat	.36	8
Tough/Damp Canola	.21	13
B.P.Grade Loss, Barley and Wheat	.71	7
Discount Wheat Grade Loss	.23	12
Discount Canola Grade Loss	.09	15
Combine Losses	1.72	2
Weathering Barley and Wheat	.30	9
Excessive Handling	.24	11
Storage/Insect Loss	.24	11

*B.P. Base Probability

a 1 percent change in the technical parameter value used in the base scenario.[23]

$$= \frac{[\text{ change in NPV/NPV}_0]}{[\text{change in parameter value/parameter value}_0]}$$

where NPV_0 and parameter $value_0$ designate the values and estimates calculated in the cost/benefit tableau for the base scenario.

The elasticity estimates indicate that variations in canola prices, followed by combine losses and wheat prices resulted in the largest variation in NPV. Consequently, the profitability of any NAD system over the likely range of values for these parameters should be carefully scrutinized by the user.

Scenario 33 - Single Batch Natural Air Drying

In the base scenario (S1), the NPV of $4,198 was relatively large providing a wide margin of profitability. However in scenario 33 where a 1.5 axial fan was used to dry a single batch of wheat in a 3,000 bushel bin, the NPV was estimated at $228 based on the parameter values indicated in Chapter 3. The NAD system proposed in this scenario is barely profitable, consequently assignations of parameter values are critical. Analyzing the percent change in the parameter values and the corresponding effect on NPV indicates which parameters cause variation in the cost benefit results, and which parameters require careful

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[23]The elasticity estimates for each parameter apply over the range of parameter values indicated in the respective tables in the appendices. For example, the barley price elasticity in scenario 1 is .72 whether barley prices fall <u>from</u> $110 to $85, or increase <u>from</u> $110 to $115. The key point is that the elasticities have been based on the technical parameter values set in the scenario, in this case $110. If the parameters for barley prices were set at $85 a new elasticity estimate would be determined as elasticity estimates depend on the reference point.

assessment. Parameter elasticities with respect to NPV are listed in Table 12 and can be compared to determine which parameters are critical to NAD profitability.

TABLE 12. PARAMETER ELASTICITIES WITH RESPECT TO NET PRESENT VALUE, SCENARIO 33.

PARAMETER	ELASTICITY	RANK
Wheat Price	22.5	1
Combine Op. Margin	6.35	5
Combine Capacity	5.29-7.96	3
B.P. Increased Combine Use*	6.35	5
Discount Tough Wheat	3.71	8
Tough/Damp Wheat	3.87	7
B.P.Wheat Grade Loss	7.70	4
Discount Wheat Grade Loss	4.25	6
Combine Losses	10.08	2
Wheat Weathering	3.45	9
Storage/Insect Loss	2.72	10

*B.P. Base Probability

It is difficult to compare the results of the sensitivity analysis between the two scenarios as the percent change in NPV resulting from parameter changes for scenario 33 will obviously be larger due to the small NPV value estimated. For example, a $100 change in the NPV is only 2 percent of the estimated NPV in scenario 1 but is 44 percent of NPV inscenario 33. However, the ranking of the parameter elasticities across scenarios provide information as to which parameters are critical to NAD profitability.

Changes in wheat price had the largest effect on NPV in scenario 33, not unlike scenario 1 where changes in the price of canola had the largest effect on NPV. Similarly, reduced combine losses, combine capacity and base probability of combine use which ranked second, third and fifth in scenario 1, ranked second, fourth and fifth in terms of their effect on NPV in scenario 33.

Adjustments to combine operating margin had a larger effect on NPV in scenario 33 than in scenario 1. The additional hours of combining time gained given the size of combine is largest for wheat as the tonnes of grain dried in the NAD bin is larger, 82 tonnes as opposed to 66 and 68 for the other two crops. Any change in combine operating margin and its effect on benefits will thus be more pronounced for wheat. Since only one batch of wheat is dried in scenario 33, the effect on NPV is more pronounced.

The discount for tough/damp wheat, wheat grade loss and base probability of storage loss and insect damage in both scenarios were small relative to the other parameters tested. Excess handling costs were not a factor in the profitability of the NAD system specified in scenario 33. Excess handling costs were zero as only one batch of grain was dried negating the need to transfer grain from one bin to the next.

Sensitivity of the B/C ratio to barley and canola prices, combine use, and percent combine and storage losses in scenario 1 are illustrated in Figures 3 to 7. The sensitivity of B/C ratio to wheat prices, combine use, percent combine losses and storage losses for scenario 33 are also illustrated in Figures 8 to 11.

FIGURE 3

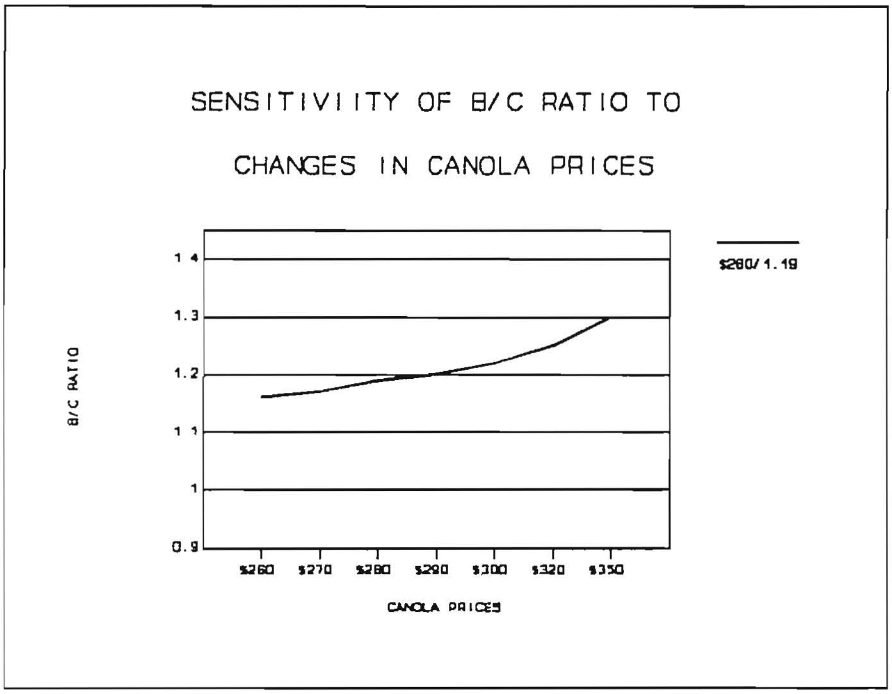


FIGURE 4

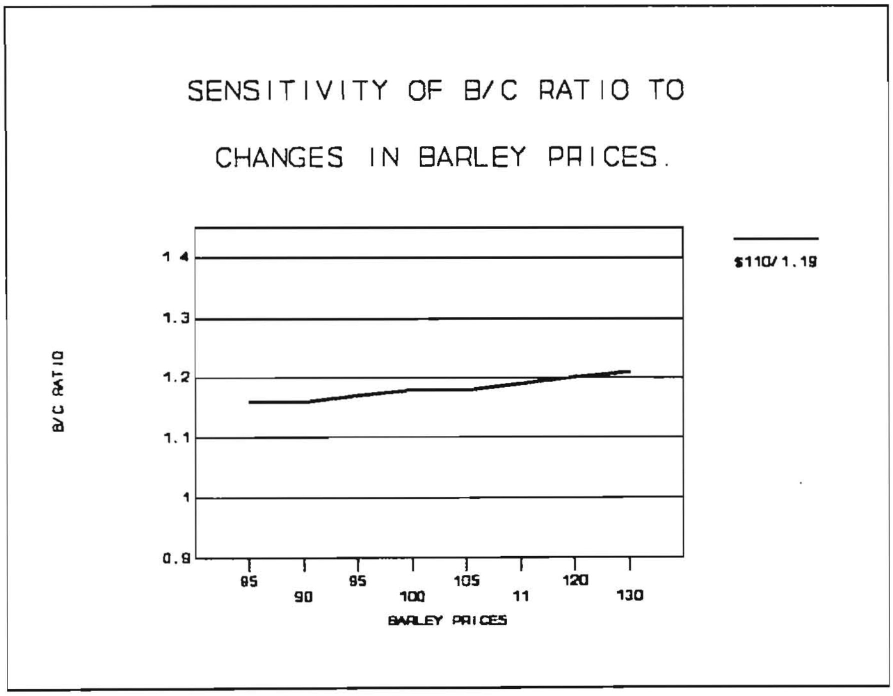


FIGURE 5

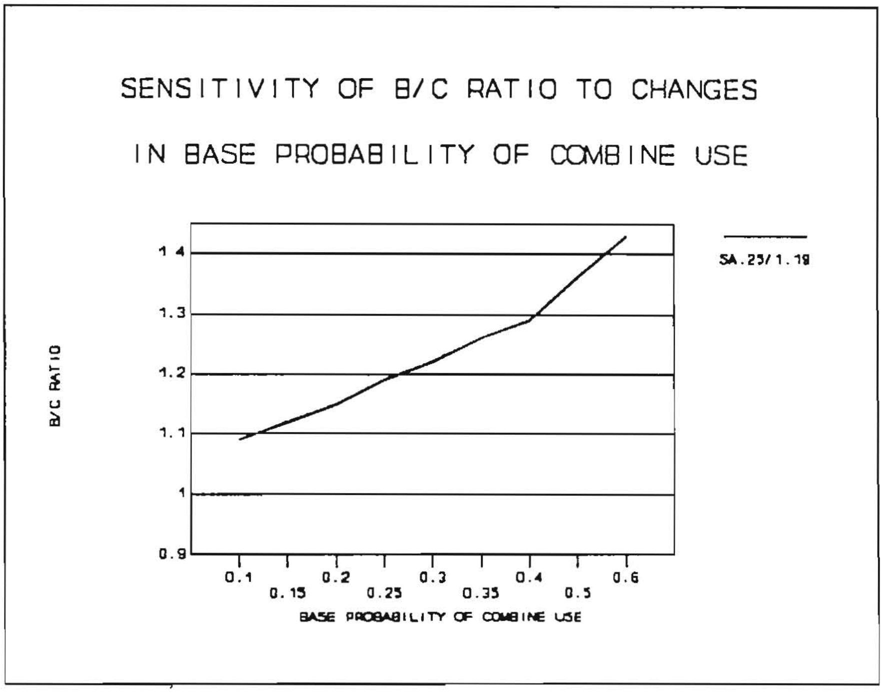


FIGURE 6

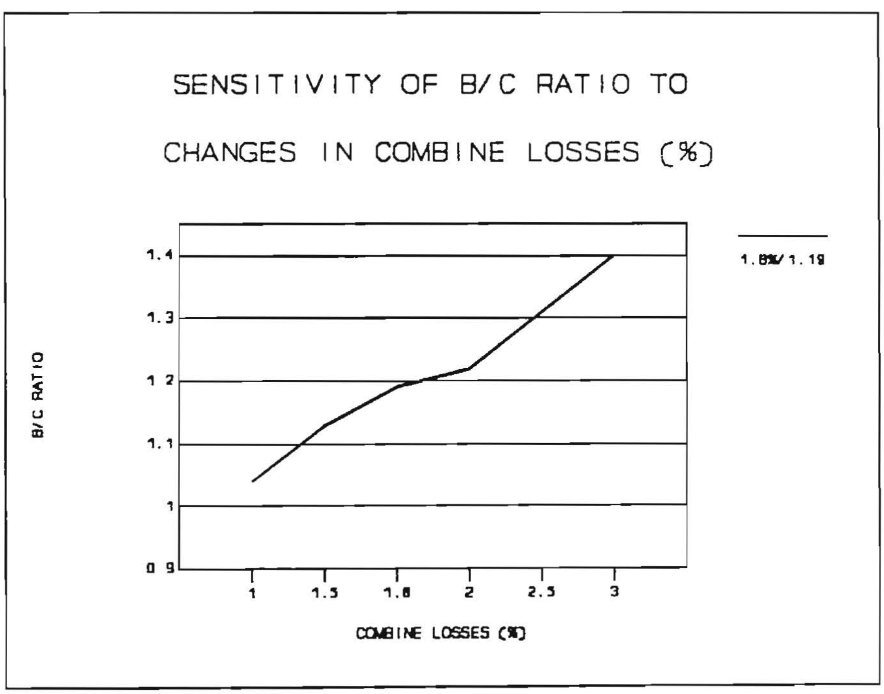


FIGURE 7

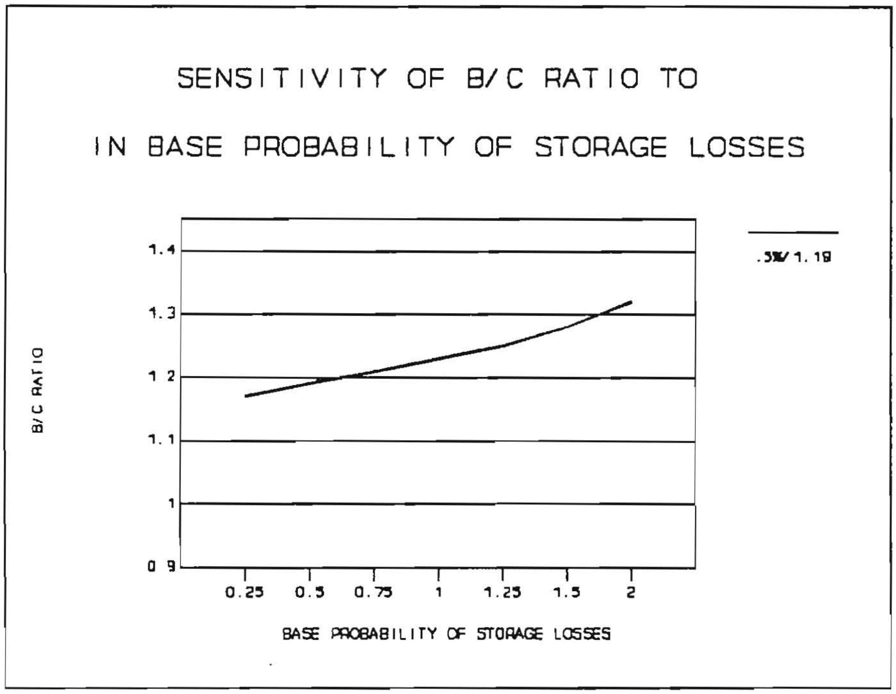


FIGURE 8

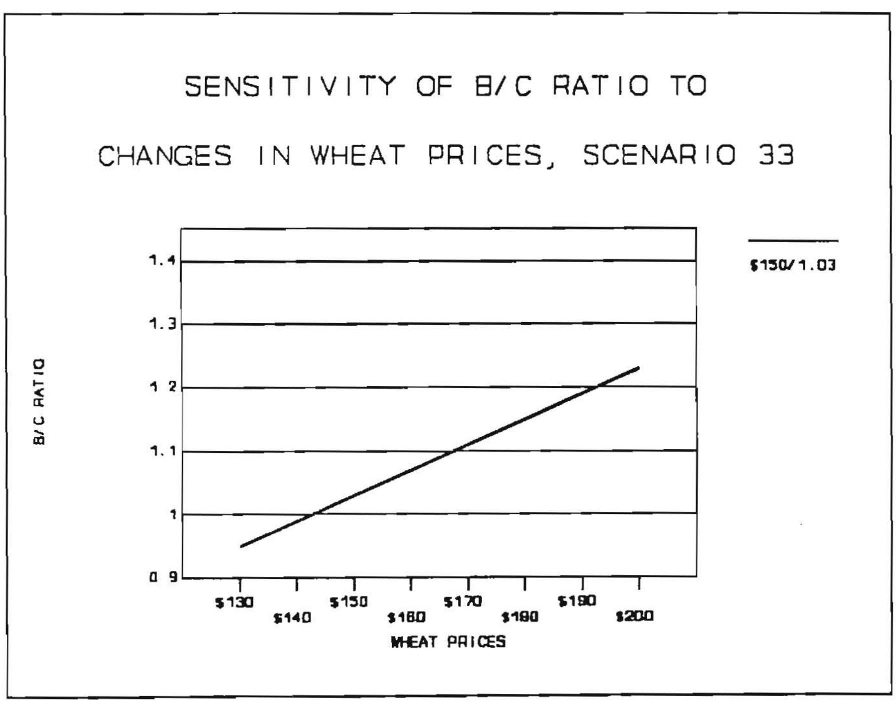


FIGURE 9

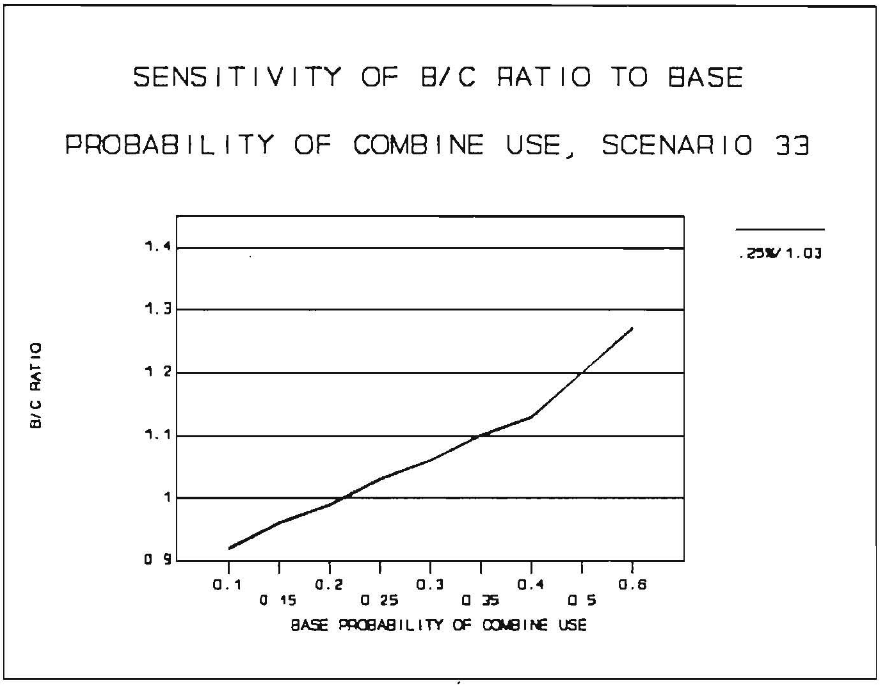


FIGURE 10

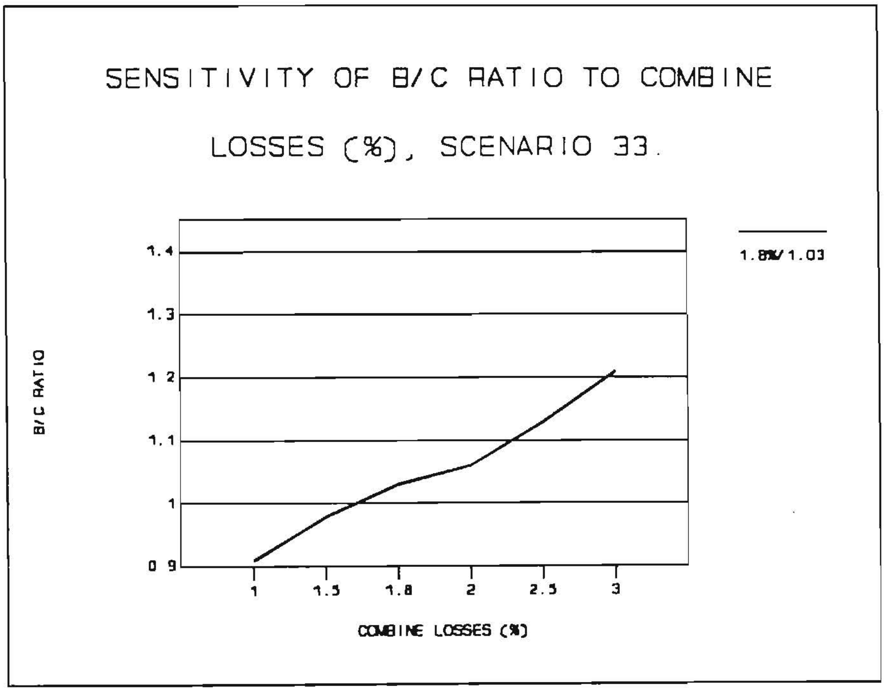
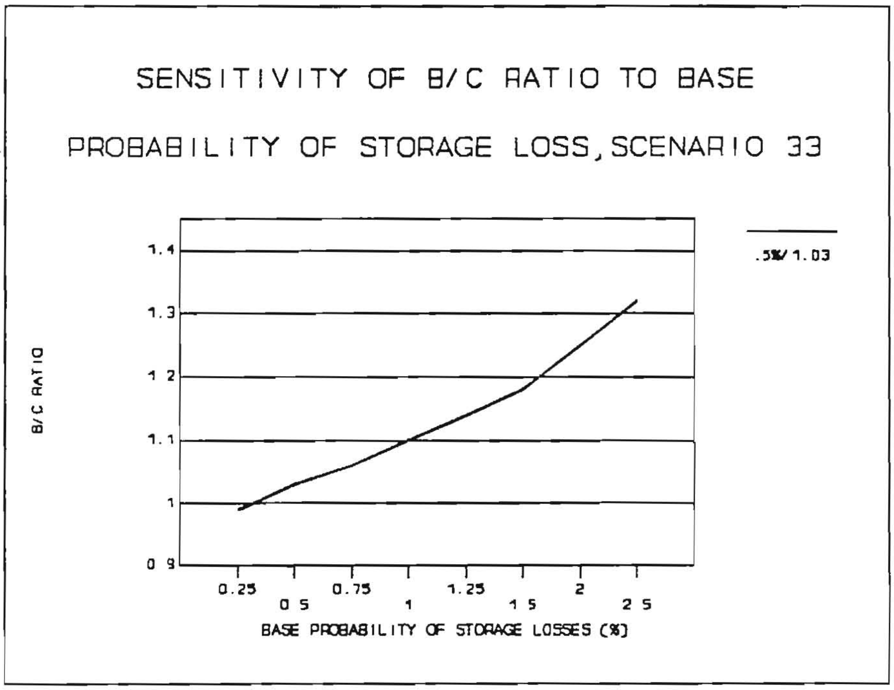


FIGURE 11


SENSITIVITY OF B/C RATIO TO BASE
PROBABILITY OF STORAGE LOSS, SCENARIO 33
B/C RATIO
1.4
1.3
1 2
1.1
1
0 9
0.25
0 5
0.75
1
1.25
1 5
2
2 5
BASE PROBABILITY OF STORAGE LOSSES (%)
.5%/1.03

SUMMARY AND CONCLUSIONS

The case study approach adopted to analyze the economics of natural air drying highlights how difficult it is to make generalizations about the profitability of NAD systems. Profitability depends on the conditions imposed on the NAD system such as 1) moisture content, 2) bin size and configuration, 3) fan size, model and type, 4) the combination of grain to be dried, 5) harvest date, and 6) the size of the initial capital expenditure. It also depends on the value of the technical parameters entered in the cost/benefit tableau. In the study, the the technical parameters values and system specifications were chosen to ensure the results were not biased in favour of the profitability of natural air drying.

The 87 scenarios analysed represented a variety of conditions which could occur in Manitoba. However, as the feasible combinations of conditions in the province are more numerous, a farmer who wishes to consider different combinations of conditions must assess the NAD system he/she proposes individually. For example, it was assumed throughout the study that the farmer does not have electrical power at the bin sites and hence must invest in installation. However, if the power is already available at the bin sites, the profitability of a system is increased as the initial capital investment is reduced. Analysis presented throughout this report indicate how these comparisons can be made using the cost/benefit tableau and sensitivity analysis.

Based on the values of the technical parameters used in this study and the various combinations of conditions imposed in the scenarios, the following generalizations are made although caution is required in their specific application.

1. Of the three crops able to be analyzed, **profitability of NAD systems increased when canola and wheat were included in the drying combinations.** Generally, the net

benefits were largest for canola followed by wheat then barley. The base NAD system showed positive returns when barley/wheat/canola, wheat/canola, and barley/canola combinations were dried. Given the level of capital investment of the base scenario, benefits generated by barley/wheat, or barley or wheat alone were not great enough to cover operating expenses and the initial capital investment. In some circumstances, low cost NAD systems (i.e. 3,000 bushel bin with small horsepower fan) used for aeration would provide minimal profitability.

2. **Increasing the size of bin while maintaining the same fan can improve profitability** provided technical drying requirements can be met. Often the system is not able to dry the grain as quickly. As a result, the number of batches of grain that can be dried in the fall is reduced. However, it is possible that even with fewer batches dried, the profitability of a system using a larger bin may be increased due to the larger volume of grain dried. The estimated benefits per tonne dried were constant, therefore, as the quantity of grain dried increased, so did the total benefits. However, per unit costs decreased as bin size increased; the capital expenditure per tonne capacity decreases with size as did the fixed costs such as maintenance, repairs and insurance.

3. **NAD is expected to produce more favourable returns in the Winnipeg area than Brandon and Dauphin.** This is partially due to lower overdrying costs which reduce the cost of natural air drying. Secondly, the precipitation patterns for the three areas indicate that the probability of a wet year during harvesting is 7 to 8 percent higher in Winnipeg, and the probability of a dry year 9 to 10 percent lower. Consequently, producers around Winnipeg could be expected to use the NAD system more. There would be greater opportunity for increased combine use in the Winnipeg area, and more likelihood of storage, grade and insect

losses without a NAD system. It should be noted that this does not suggest that natural air dyring in Brandon or Dauphin is unprofitable, as there were many situations where natural air dyring was profitable in both locations.

4. Of the bins tested, **wider squat bins used in NAD systems appeared to produce more favourable economic results than taller narrower bins because** 1) grain could be dried more quickly thereby increasing drying flexibility (number and types of grain dried) and 2) overdrying costs were less.

5. **Analysis of fan size indicates the critical importance of matching fan and bin size with the grains to be dried.** While a smaller fan on the same size bin may not have the drying flexibility of a larger fan matched with the same bin, the NAD system using the smaller fan may be more profitable depending on the difference in capital expenditure between the two fans. For example, it was shown that a 5 hp fan matched with a 3,000 bushel bin drying barley/wheat was more profitable than a 10 hp fan drying the same combination. The capital investment in the smaller fan was approximately $800 less thereby improving the profitability of the smaller power NAD system. The important point to notice here is that the profitability of the system is contingent on the grains dried. Analysis indicated that the larger system was able to dry barley/wheat/canola resulting in a NPV three times that of the smaller system drying barley/wheat. However, if the farmer planned on drying only barley and wheat the smaller NAD system would be more profitable.

6. **Installation of a NAD system based on fans currently on the farm may not be the most profitable investment for any given operation.** Assuming moisture levels of 18.8 and 18.5 percent for barley and wheat respectively, a 1.5 hp axial fan matched with a 3,000 bushel bin could not profitably dry either barley or wheat. The benefits of drying a

single batch like these were not large enough to offset the initial capital investment in the NAD system which would do the job. However, at lower moisture contents of 16.8 and 16.5 percent, the cost of drying decreased and the system was able to dry both barley and wheat, thereby increasing the benefits. In cases where the fan was already used on the farm, the capital investment in the fan would be zero. In these circumstances the low cost system devised would be profitable but not necessarily the most profitable as it pays off only under very restrictive conditions.

7. A smaller horsepower fan that is physically capable of drying the same combinations of grain as larger fans does not guarantee that the NAD system using the smaller fan is more profitable. It is possible that overdrying costs with the smaller fan may exceed the price difference between fans.

8. **Different types of fans, centrifugal, in-line centrifugal and axial of the same horsepower can not be substituted for each other or assumed to generate the same economic performance.** Each type of fan has different performance characteristics and capital costs which affect the profitability of the NAD system. The performance of each fan must be tested within a rather complex analytical framework in order to determine the economic implications of its use.

9. **NAD systems appear to be more economical if the fan is left running continuously.** The evidence produced here indicates that humidistat control not only increases drying time and reduces drying flexibility, it is an unnecessary capital expenditure.

10. In 7,500 and 10,000 bushel bins, if the addition of stirring devices enabled producers to get an accurate reading of average moisture content in the grain, the capital

investment in stirring devices is worthwhile[24]. The results of the cost/benefit analysis indicated that the **NPV increased two to three times when average bin moisture content was used as a means of determining when drying was complete.**

In summary, natural air drying appears to provide the potential for positive payoffs provided equipment is matched to needs. Choosing the appropriate NAD system, however, is a complicated process as 1) there is a large selection of equipment models, types and sizes, 2) technical and price parameters affecting profitability are constantly changing and 3) financial conditions on-farm are subject to change as are producer risk preferences.

Costs of operating a NAD system arise from 1) system investments which are known and easily identified, and 2) operating costs which can be very important but not easily determined. Overdrying costs are particularly critical to economic viability of a NAD system emphasizing the need to match bin and fan, but also emphasizing the need for research and technological innovation towards on-farm capability of drying grain to average moisture content.

Increased combine usage, increased sale of straight grades, reduced weather damage, reduced overdrying in the field, increased quantity harvested, reduced weightloss from weathering, decreased storage and insect losses are sources of benefits associated with natural air drying. The magnitude of these benefits vary with the conditions under which the NAD system must operate but generally increased combine usage and reduced combine losses contributed the largest sources of benefits generated by NAD systems.

[24]The effect of stirring devices on drying time is not known. Therefore, if the drying time is underestimated so will the drying costs and the profitability overestimated.

LIMITATIONS AND FURTHER RESEARCH

The analyses indicated that natural air drying appears to provide a positive payoff. However, further research is required to determine both the accuracy of the benefits estimated and the benefits generated under a number of alternative conditions not analyzed in the study. Further research in the following areas is recommended:

1. Technical information is required to determine how storage and insect losses vary with grain moisture content in the bin, and the size of bin. In the study, the base probabilities of storage and insect losses were invariant with moisture content and the size of bin. This resulted in an underestimation of the benefits of harvesting grain at higher moisture contents and the use of NAD systems with larger bins. Research indicates that the temperatures in the core of larger bins in January and February are frequently above freezing, consequently storage losses from insect damage and heating can be large.

2. Straight combining which has become a popular practice in the Prairies is facilitated by natural air drying. It allows grain that otherwise would have been swathed and left in the field to dry, to be harvested at higher moisture contents. This "advanced" harvesting system which bypasses swathing and uses straight combining in conjunction with NAD is shown in Figure 1. The additional benefits attributed to this advanced NAD system include i) a maximum increase in combine usage as the harvest season is extended, ii) further reduced risk of hot spots due to green grain and seeds in wheat, barley and flax and iii) decreased harvesting costs. These variations could be estimated with minor alterations in the existing framework developed in the study. Given the possible added indirect benefits of NAD, it may be reasonable to assume that the profitability of NAD indicated in the study are conservative.

3. The economics of using a NAD system in conjunction with a conventional hot air drying system can also be tested with minor alterations to the existing framework. A NAD system can be used either to remove the last 1 to 2 percent of excess moisture or cool down the grain after it is dumped directly into a NAD bin. Alternatively, the profitability of a NAD system relative to a hot air grain dryer can be compared when only 1 to 2 percent moisture must be removed.

4. The study results indicated that the profitability of NAD could increase by two to three times if grain could be dried to average moisture content. The primary reason for this result is the decreased loss in value associated with overdrying and reduced drying costs. In addition, drying time would be quicker opening the opportunity for multiple batch drying, thereby increasing benefits generated. As it is difficult to determine average moisture content in the bins, particularly with the larger bins, it would be useful to develop a simulation program that determined drying costs and the time to reach average moisture content when stirrers were used. If the drying costs and time estimated in those scenarios where grain was dried to average moisture content are indicative of the results that could be ascertained using stirrers, the capital investment in large NAD systems would appear to be extremely profitable.

For smaller bins it would also be useful if simulations were developed to determine the effect of rotating the grain manually by unloading from the bottom and refilling from the top. The effectiveness of this practice in reducing drying time and costs could then be better assessed.

5. The MDA computer simulation program was unable to determine drying costs and times for either hopper bins or flax. As the use of hopper bins is not insignificant and flax is a relatively high valued crop, it would be useful if simulations were developed for

these alternatives. The cost/benefit tableau could then be extended and adjusted to account for the extra oilseed, and the different costs associated with hopper bins.

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APPENDIX 1

Natural Air Drying Cost Benefit Analysis Tableau
Instruction Manual

INSTRUCTION MANUAL TO ACCOMPANY NAD SPREADSHEET

The purpose of this manual is explain the outline and formulas used in the cost benefit tableau developed to determine the profitability of NAD systems. The spreadsheet is written in QUATTRO and is located in the file titled **NADCBA.WKQ.**[1] **If any changes are made to the master copy of the spreadsheet the amended spreadsheet must be saved under a different name in order to protect the master copy i.e., save as OWNCBA.** The spreadsheet is composed of four sections including:

(i) Parameter estimates
(ii) Costs of NAD
(iii) Benefits of NAD
(iv) Evaluation criteria
(v) Sensitiviy Analysis

The spreadsheet can be used to evaluate up to three crops (barley, wheat and canola) at three locations (Winnipeg, Brandon and Dauphin) in Manitoba. The lifespan of the investment has been set at 15 years. Each of the four sections will be discussed in turn and the cell entries explained as they appear in the master copy of the spreadsheet.

I. PARAMETER ESTIMATES

There are two sources for the parameter estimates used in the worksheet. First, a 1986 Manitoba Department of Agriculture (MDA) computer simulation of a NAD system was used to generate technical and cost information for the actual drying of the grain in the bin. Second, all other technical and price parameters were developed by the authors through research, discussions with experts and farmers, as well as their own experience with grain

[1]The number 15 in the title of the file refers to the length of the investment period while the letters EV refer to expected value, the basis for adjusting estimated probabilities to account for differences in precipitation at harvest.

production in Manitoba. In general, the term program as used in this manual refers to the MDA computer simulation while the term spreadsheet or tableau refers to the computer spreadsheet developed in the course of this study. The parameter estimates for years 2 to 15 are in most cases anchored to the year 1 value. For instance, if a use rate of 1 is entered for canola, the same use rate is automatically entered in years 2 to 15. However, the user of the spreadsheet is allowed to change the value of the parameter for any year, i.e., year 7 or years in order to accommodate his or her own unique circumstances but leave unchanged the parameter values in subsequent years. For example, the user can decide to dry three crops in all years except year 7, or he/she may decide to try two grains year 7, and one grain year 10.

Parameters values which the user must input are indicated at the beginning of each discussion of the relevant parameters by USER. Parameter estimates are discussed below under their spreadsheet headings.

Section 1

USER 1. Real Price Ratio: (Year t/Year t-1). This parameter allows the operator to account for any anticipated change over time in the price of the grain. Only one rate of change can be entered for the entire investment period. For example, if it is anticipated that the real price of barley will decline by 2 percent per year over the life of the investment this parameter would be set at 0.98.

USER 2. Fan Identification. The model number of the fan is entered only for reference purposes so that different NAD systems are more easily distinguished.

USER 3. Drying Time. The time required to dry each grain is entered also for reference purposes. If the grain is not dried within the time frame allocated for the next grain to be dried a negative sign can be entered to indicate this. For example, grain if wheat were harvested September 7, then wheat must be dried within 24 days if canola is to be dried October 1.

USER 4. Flooring and Point of Moisture Specification. If a cereal floor or an average moisture measurement is selected in the MDA computer simulation run, these factors can be documented on the spreadsheet by striking the F2 (edit function key) and retyping the correct information. Press the enter key after the information is entered to document the change.

USER 5. Weather Conditions. In order to account for the impact of weather conditions at harvest on costs and benefits, a rainfall probability distribution for each of the three locations (Winnipeg, Brandon and Dauphin) in the province based on the past 100 years (approximately) of rainfall data for the months of August and September were calculated. The probability distributions for Brandon and Dauphin were based on average precipitation values for Winnipeg as the technical parameters in the program are based on Winnipeg precipitation. **Possible harvest weather conditions were divided into "dry" (less than 90 percent of average Winnipeg precipitation), "average" (between 90 and 110 percent of average Winnipeg precipitation), or "wet" (greater than 110 percent of average Winnipeg precipitation).** The probability of a dry, normal or wet year is entered in the spreadsheet from the table below. These probabilities are used to weight those parameter estimates that vary with weather conditions at harvest. The following parameters are weighted by the probabilities entered here: **Probability of Increased Combine Use; Damp/Tough Ratio;**

Proportion of Harvest Tough/Damp; Probability of Grade Loss; Weight Loss due to Weathering; Probability of Increased Storage Loss; Probability of Increased Insect Damage.

Section 2

MDA Computer Simulation Parameters. The following are the technical parameters provided by the MDA computer simulation of a NAD system.

USER 1. **Location**. Any NAD system which is to be investigated can be evaluated at three locations in Manitoba: Winnipeg, Brandon and Dauphin. Costs of drying the crop in the bin are calculated by the MDA program and are based on the past 33 years of observed weather during August to November at each of these locations. The user sets the location for year 1 and the spreadsheet automatically updates the location for years 2 to 15.

USER 2. **Grain**. In order to simplify the spreadsheet, the user is given the option of using the NAD system to dry up to three grains in any one year. Only one batch of each crop can be dried each year. As some of the calculations in the spreadsheet are crop specific these three cell entries (Barley, Wheat, Canola) are not to be changed.

USER 3. **Harvest Date**. The harvest date must be specified to run the MDA program. The date from that program in entered here (for information purposes only; there is no effect on the results in this spreadsheet). The user sets the harvest date for each crop in year 1 and the spreadsheet automatically adjusts the dates for years 2 to 15. Adjustments made in a particular year (except year 1) do not affect subsequent years.

USER 4. **Moisture Content at Harvest.** This parameter is set as for the harvest date above. This parameter is included for information purposes only as it has no effect on the results in this spreadsheet.

USER 5. **Price (No.1) ($/mt).** The user indicates the grain price he/she believes appropriate. This may be either the current grain price, the expected price next year or an average price of past trends. In years 2 to 15, however, the price appearing in these cells will vary from that entered in year 1 if the real price ratio is assumed to change, i.e., if a change in real prices is predicted.

USER 6. **Bin Size (tonnes and bushels).** The size of the bin in bushels can be changed by striking the F2 function key which permits correction of the written label " Bin size (3,000 bu)." For instance, if a 5,000 bushel bin is used in the designated NAD system, the user may wish to document this fact in the label to distinguish the results of different NAD systems. Note that the bin capacity indicated here is simply a category designation and is based on the assumption that the cone of the bin is filled. <u>This is not to be confused with the actual volume of grain dried in the bin which assumes that the bin is filled to the eaves and is documented in tonnes.</u>

In the master copy of the spreadsheet, the bin size has been set at 66 tonnes, 82 tonnes and 68 tonnes (3,000 bushels) for barley, wheat and canola respectively. This is really the actual quantity of grain dried, therefore the technical size of the bin for NAD purposes. If the bin size or configuration is changed, input the information entered in the MDA computer simulation. It is assumed that the bin is filled <u>level with the eaves</u> as this is reported to be the most efficient configuration for drying the grain. The user sets the bin size in tonnes for each batch in year 1 and the spreadsheet automatically adjusts the bin size for years 2 to 15. If **Bin Size** is changed it will also be necessary to change the technical parameters for **Bin Diameter**, **Grain Depth**, **Quantity Dried** and **Airflow** as well as the cost entries for **Perforated Floor and Supports**, **Transition and Vents** and possibly **Fan** (if a different fan is required).

USER 7. **Bin Diameter (metres).** In the master copy of the spreadsheet, the bin diameter has been set at 5.50 metres. If a different bin size or configuration is used, enter the specifications entered in the MDA simulation. Changes to this parameter are made as for **Bin Size** above.

USER 8. **Grain Depth (metres).** In the master copy of the spreadsheet the grain depth has been set at 4.50 metres. As in bin size and diameter, the depth must be adjusted if bin size or configuration has been altered.

9. Quantity Dried (tonnes). This is the same as bin size and is automatically adjusted. It is the capacity of the bin when filled level with the eaves.

USER 10. **Airflow (l/sec/cu m).** In the master copy of the spreadsheet the airflow has been set at 19.7, 19.2 and 15.5 for barley, wheat and canola respectively (it is the value appearing in the MDA computer simulation for each of the three crops). This will change with the fan chosen, the bin size and bin configuration. The value of this parameter is included in the spreadsheet for information purposes only as changing it has no effect on the costs and benefits estimated by the CB tableau.

USER 11. **Fan Operating Cost ($).** This cost is taken from the MDA computer simulation. The user enters the values for each of **Batch Nos.** 1, 2 and 3 in year 1 and the spreadsheet adjusts the respective value for the corresponding batch in years 2 to 15 (Batch No. 1 has the same value for each of the years in the spreadsheet). Adjustments made in a particular year (except year 1) do not affect subsequent years.

USER 12. **Bin Overdrying Cost ($).** The MDA computer simulation calculates this cost on the basis of the average moisture content of the grain and the current price for that grain. This cost is entered as for **Fan Operating Cost** above. In years 2 to 15, overdrying costs are adjusted to take into account any change in relative prices which has been entered above. Adjustments made in a particular year (except year 1) do not affect subsequent years.

USER 13. Average Bin Moisture. This value is taken from the MDA computer simulation program and is included here for information purposes only. Changing the value of this parameter has no effect on the results.

Section 3

Other Parameters

The following parameters were estimated by the authors through a review of previous research and consultation with other experts and farmers.

USER 14. Use Rate (batches dried/year). The user of the spreadsheet must set this parameter for each crop (Batch no.) in year 1. If the bin is used for that crop in that year the parameter is set equal to 1, otherwise it is set equal to 0. The spreadsheet adjusts the corresponding batch for years 2 to 15, i.e., if the user sets this parameter for batch no. 1 in year 1 to the value 1, batch no. 1 in all other years will take the value 1. The user has the option of changing this value in any particular year by entering either 0 (bin not used for that crop that year) or 1 (bin used for that crop that year). All subsequent years are unchanged (they retain the value set in year 1).

USER 15. Combine Operating Margin ($/hr). It is expected that the combine margin will be the same for the three grains but they can be different if desired. The user enters the value he believes he can earn from his/her combine and the demand for extra combine time his area.

USER 16. Combine Capacity (mt/hr). The user enters the estimated capacity of his/her combine in tonnes per hour for each crop in year 1 and the spreadsheet adjusts the corresponding values in years 2 to 15. For example, a 1HL1680 might be expected to produce 1,000 bus/hr or 20 mt/hr. That combine would fill a 3,000 bushel bin in just over three hours.

USER 17. **Base Probability of Combine Use.** The base probability has been conservatively set at 0.25 on the assumption that the farmer will make use of only 25 percent of the extra combining time available to him in a normal year, i.e., if the farmer has an extra 10 hours of combine time available through installation of a NAD system he will actually use the combine an extra 2.5 hours. Adjustments made in a particular year (except year 1) do not affect subsequent years.

18. Probability of Increased Combine Use. The user does not enter a value in this cell. The spreadsheet automatically sets the value of this parameter on the basis of the value inputted by the user for **Base Probability of Combine Use.** An adjustment is made to reflect the likelihood of increased combine use in dry (weighting factor of 0.5), normal (weighting factor of 1.0) and wet (weighting factor of 1.5) years. For example, for a NAD system installed in Winnipeg, if the **Base Probability of Combine Use** is set at 0.25, the **Probability of Increased Combine Use** will be 0.2275 {0.25 x [(**Probability of a Dry Year** x 0.5) + (**Probability of a Normal Year** x 1.0) + (**Probability of a Wet Year** x 1.5)]}. This number is rounded up to 0.23 in the spreadsheet display although the spreadsheet uses 0.2275 for calculations.

USER 19. **Discount for Tough Grain ($/mt).** This parameter is set by the user for each crop in year 1 and the spreadsheet adjusts the corresponding value in years 2 to 15.

USER 20. **Discount for Damp Grain ($/mt).** This parameter is set by the user for each crop in year 1 and the spreadsheet adjusts the corresponding value in years 2 to 15.

USER 21. Damp/Tough Ratio. This parameter is not set by the user. The ratio indicates the breakdown of grain harvested above acceptable moisture contents. For example, a base value of 0.25 was selected, indicating that, in a normal year, of all grain harvested above the allowable moisture content for straight grades 75 percent is tough and 25 percent is damp. The base value is adjusted to account for expected weather conditions at different locations in the province by weighting this ratio on the basis of the probabilities entered from Table 1.

USER 22. Base Proportion of Harvest Tough/Damp. This parameter indicates the proportion of grain harvested above straight grades in any one year. The default value is set at 0.15 for barley and wheat and 0.10 for canola, i.e., 85 percent of barley is harvested dry in normal years. The user can set this parameter for each crop in year 1 and the spreadsheet adjusts the corresponding values for years 2 to 15. Adjustments can be made for individual years (except year 1) without affecting subsequent years as each year is anchored to year 1.

Table 1

Precipitation Probability Distribution, August to October

	Location		
% of Average	Winnipeg	Brandon	Dauphin
< 90	43.1	53.5	51.9
90 < actual < 110	19.0	15.2	18.2
> 110	37.9	31.3	29.9

Source: Estimated by authors from Environment Canada data.

USER 23. Proportion of Harvest Tough/Damp. The value of this parameter is set by the spreadsheet after the **Base Proportion of Harvest Tough/Damp** is set by the user.

The value in the previous entry is multiplied by 0, 1.0 or 2.0 in the spreadsheet to reflect conditions in dry, normal and wet years respectively, i.e., if a base value of 0.15 is selected for a location at Winnipeg, the corresponding value in this cell is 0.12 {0.15 x [(0 x **Probability of a Dry Year**) + (1.0 x **Probability of a Normal Year**) + (2.0 x **Probability of a Wet Year**)]}.

USER 24. Base Probability of Grade Loss. This parameter is set by the user and is the proportion of grain harvested and placed in a NAD system that would have suffered a grade loss due to excess moisture after maturation i.e., if this parameter is set at 0.25, in a normal year of 100 tonnes of grain placed in a NAD bin 25 tonnes would have suffered a grade loss if left to dry in the field. Adjustments can be made for individual years (except year 1) without affecting subsequent years as each year is anchored to year 1.

25. Probability of Grade Loss. This parameter is set by the spreadsheet after the **Base Probability of Grade Loss** is set by the user. The value in the previous entry is multiplied by 0.25, 1.0 or 1.5 in the spreadsheet to reflect conditions in dry, normal and wet years respectively. Calculations are similar to those for **Proportion of Harvest Tough/Damp** above.

USER 26. Discount for Grade Loss ($/mt). The user enters the discount on one grade loss for canola and barley and wheat.

27. Probable Discount for Grade Loss ($/mt). For barley and canola this is simply the discount entered for parameter 26. Discounts for barley and canola is equal to the price difference between number 1 and 2 as it is unlikely that either of these crops would loose two grades because of weathering. For wheat, however, it is necessary to account for the possibility of the grade falling from number 1 to number three. In the case of wheat, the base discount of $3.00 is weighted by the probabilities entered from Table 1. For example, for a Winnipeg location, this parameter is set at $5.27 = {$3.00 x [(**Probability of a Dry Year** x 1.0) + (**Probability of a Normal Year** x 1.0) + (**Probability of a Wet Year** x 3.0)]}. The number 3.0 indicates that in a wet year it is 3 times as likely that wheat will suffer a loss of 2 grades compared to normal or dry years. Adjustments can be made for individual years (except year 1) without affecting subsequent years as each year is anchored to year 1.

USER 28. **Reduced Combine Losses** (%). This parameter can be set by the user for each grain in year 1 and the spreadsheet adjusts the values for the corresponding crop in years 2 to 15. The default has been set at 1.8 percent for barley with wheat and canola anchored to this value in order to permit sensitivity testing of this parameter. Adjustments can be made for individual years (except year 1) without affecting subsequent years as each year is anchored to year 1.

USER 29. **Base Weight Loss due to Weather** (%). This parameter can be set by the user for each crop in year 1 and the spreadsheet adjusts the corresponding values for years 2 to 15. Adjustments can be made for individual years (except year 1) without affecting subsequent years as each year is anchored to year 1.

30. **Weight Loss due to Weathering** (%). This parameter is set by the spreadsheet after the **Base Weight Loss due to Weather** is set by the user. The value in the previous entry is multiplied by 0, 1.0 or 2.0 in the spreadsheet to reflect conditions in dry, normal and wet years respectively. Calculations are similar to those for **Proportion of Harvest Tough/Damp** above.

USER 31. **Excess Handling Cost ($/mt).** This parameter can be set by the user for each crop in year 1 and the spreadsheet adjusts the corresponding values for years 2 to 15.

Adjustments can be made for individual years (except year 1) without affecting subsequent years as each year is anchored to year 1.

USER 32. Base Probability of Storage Loss (%). Grain stored in a nonaerated bin is more subject to damage from mould or fungus because of the possibility of pockets of heat or moisture occurring. This parameter can be set by the user for each crop in year 1 and the spreadsheet adjusts the corresponding values for years 2 to 15. Adjustments can be made for individual years (except year 1) without affecting subsequent years as each year is anchored to year 1.

USER 33. Probability of Increased Storage Loss (%). This parameter is set by the spreadsheet after the **Base Probability of Storage Loss** is set by the user. The value in the previous entry is multiplied by 0.5, 1.0 or 1.5 in the spreadsheet to reflect conditions in dry, normal and wet years respectively. Calculations are similar to those for **Proportion of Harvest Tough/Damp** above.

USER 34. Base Probability of Insect Damage (%). Grain stored in nonaerated bins also is more subject to damage from insects because of the potentially warmer and wetter conditions in these bins (although there are no estimates of the amount of revenue lost each year through insect damage). This parameter can be set by the user for each crop in year 1 and the spreadsheet adjusts the corresponding values for years 2 to 15. Adjustments can be made for individual years (except year 1) without affecting subsequent years as each year is anchored to year 1.

35. Probability of Increased Insect Damage (%). This parameter is set by the spreadsheet after the **Base Probability of Insect Damage** is set by the user. The value in the previous entry is multiplied by 0.5, 1.0 or 1.5 in the spreadsheet to reflect conditions in dry, normal and wet years respectively. Calculations are similar to those for **Proportion of Harvest Tough/Damp** above.

II. COSTS OF NATURAL AIR DRYING SYSTEM

Section 4

The investment cost of a NAD system are broken down into its individual components. USER **Capital Costs** The user enters the costs for each of the categories, 1) ELECTRICAL INSTALLATION 2) PERFORATED FLOOR AND SUPPORTS, 3) FAN AND STIRRING DEVICES and 4) TRANSITIONS AND VENTS. These costs are entered for year 1 only.

Section 5

The user is not required (or allowed) to make any entries after this point on the spreadsheet as the spreadsheet calculates all remaining costs and benefits.

Annual Operating Costs. These costs are calculated by the spreadsheet and are explained below.

Fan Operating Expenses (from simulation). Electricity costs are entered if the NAD system is used to dry a given crop in a given year. The spreadsheet calculates this entry as follows: {**Fan Operating Cost x Use Rate**}.

Repair and Maintenance. Annual repair and maintenance costs are assumed to be 8 percent of the original installed cost for the perforated floor, supports, transition and vents and 3 percent of the fan purchase price (no repair costs are entered for the electrical installation). These costs are adjusted on the basis of the number of batches dried each year in order to reflect the fact that they increase with use. If the NAD system is not used in any one year the fixed costs of repair and maintenance are apportioned equally between each of the three batches. The spreadsheet calculates this entry through the use of a logical function as follows: **{If system is not used enter: [(Fan x 0.03) + (Perforated Floor and Supports + Transition and Vents) x 0.08] x 1/3; if system is used enter:[(Fan x 0.03) + (Perforated Floor and Supports + Transition and Vents) x 0.08] x 0.67}** x **[Use Rate (for this crop) divided by the sum of the Use Rates for all crops this year] + [(Fan x 0.03) + (Perforated Floor and Supports + Transition and Vents) x 0.08] x 0.33 x Use Rate.** If the system is used the second half of this equation estimates both the fixed and variable costs of repair and maintenance for the system.

Insurance (1% of capital cost). Insurance costs are estimated to be 1 percent of the installed cost of the system and are apportioned on the basis of **Use Rate** i.e., if the system is used to dry only two batches in a given year insurance costs will be evenly split between those two batches with the entry for the third batch set to zero. If the system is not used in any one year insurance costs are divided equally between each of the three batches. The spreadsheet calculates this entry through the use of a logical function as follows: **{If system is not used enter: Total Capital Costs x 0.01 x 1/3; if system is used enter; [Total Capital Costs x 0.01 x Use Rate (for this batch)] divided by the sum of the Use Rates for all crops that year}.**

Excess Handling (based on Use Rate). The reason for this entry has been explained earlier under **Other Parameter Estimates.** The spreadsheet calculates this entry as follows for **Batch No. 1: {Quantity Dried x Excess Handling Cost ($/mt) x Use Rate (Batch No. 2) x Use Rate (Batch no. 1)}.** For Batch No. 2 the calculation is: **{Quantity Dried x Excess Handling Cost ($/mt) x Use Rate (Batch No. 3) x Use Rate (Batch no. 2)}.** The entry is set to zero for Batch No. 3 as the NAD bin can be used for storage after drying this batch of grain.

Overdrying Costs (from simulation). Provided the bin has been used to dry this batch this year the spreadsheet enters the cost as recorded in **Bin Overdrying Cost ($)** above. The spreadsheet calculates this entry as follows: {**Bin Overdrying Cost x Use Rate**}.

III. BENEFITS OF NATURAL AIR DRYING SYSTEM

Section 6

The benefits of the NAD system are based on the parameter estimates entered above and are discussed under the following spreadsheet headings.

Increased Combine Usage (hrs x $/hr). The value of a NAD system in increasing the use rate of a farmer's combine was discussed above under **Base Probability of Increased Combine Use.** The spreadsheet calculates this entry as follows: {(**Bin Size/Combine Capacity) x Combine Operating Margin x Probability of Increased Combine Use x Use Rate (for this batch)**}.

Increased Sales of Straight Grades. A certain percentage of all grain harvested in a given year is taken off in either a tough or a damp condition. In the absence of a NAD system this grain must be either custom dried or sold at a discount. A farmer who installs a NAD system can be assumed to receive a benefit (for part of the grain dried in that NAD system) that is equal to the discount for tough or damp grain. The spreadsheet calculates this entry as follows: {**Quantity Dried x Proportion of Harvest Tough/Damp x [Discount for Tough Grain x (1 - Damp/Tough Ratio)+ (Discount for Tough Grain + Discount for Damp Grain) x Damp/Tough Ratio] x Use Rate**}. The first part of this equation estimates the quantity of grain that would have been either tough or damp and the second part calculates a blended price for tough and damp grain.

Reduced Weather Damage (grade). As noted earlier, grain subjected to excess moisture after maturation may be reduced in grade and hence bring a lower return to the farmer. A NAD system can reduce these losses by allowing earlier combining as well as increased hours of combining per day. The spreadsheet calculates this entry as follows: {**Probability of Grade Loss x Discount for Grade Loss x Quantity Dried x Use Rate**}.

Reduced Overdrying in Field (1.0%). In the absence of a NAD system a farmer must wait to begin combining until the grain has dried in the field. As a result some of the grain generally will be taken off at a lower moisture content than required thus reducing returns for the crop. This spreadsheet assumes that if the farmer waits until the grain is dry before beginning combining the average moisture content of the grain in the bin will be at least 1 percent below dry, i.e., 13.5 percent moisture for wheat versus an allowable moisture content of 14.5 percent. It has been estimated that each one percent of moisture removed from the grain reduces the saleable weight of that grain by approximately 12 kilograms per tonne. The spreadsheet calculates this entry as follows: {**0.012 x Price x Quantity Dried x Use Rate x [(1 - Proportion of Harvest Tough/Damp) x ((Probability of Dry Year x 1) + (Probability of Normal Year x 0.5) +(Probability of Wet Year x 0.25)**]}.

Reduced Combine Losses. The rationale for this entry was explained above. This entry is calculated as follows: {**Reduced Combine Losses/100 x Price x Quantity Dried x Use Rate**}.

Reduced Weight Loss from Weathering. The rationale for this entry was explained above. This entry is calculated as follows: {**Weight Loss due to Weathering/100 x Price x Quantity Dried x Probability of Grade Loss x Use Rate**}.

Decreased Storage Losses. The rationale for this entry was explained above. This entry is calculated as follows: {**Price x Quantity Dried x (Probability of Increased Storage Losses/100) x Use Rate**}.

Decreased Insect Infestations. The rationale for this entry was explained above. This entry is calculated as follows: {**Price x Quantity Dried x (Probability of Increased Insect Damage/100) x Use Rate**}.

Improved Treatment in Bin. Installation of a NAD system not only reduces the probability of storage losses and insect damage to grain in the bin, it also facilitates treatment of any problems which do occur. For example, it may be possible to treat grain in the bin by using the fan to administer chemicals rather than having to move the grain if it is not stored in a NAD system. Benefits accruing under this entry would, of course, only relate to potential losses not accounted for under the two previous categories. No estimates of the benefits of improved treatment in the bin are available and in light of the two previous entries they have been set at zero in the base case.

Section 7

Summary of Annual Results

The total annual costs, benefits, resulting net benefits and annual benefit cost ratio is calculated. This allows any producer who currently has a NAD system to determine the profitability of that system under the assumption that the investment cost is sunk and thus is irrelevant to the issue of profitability at that point. Note that investment costs are not included in this section but considered in the evaluation criteria.

IV. EVALUATION CRITERIA (Years 1 TO 15)

Section 8

The evaluation criteria used in the analysis are those typically used in investment analysis, namely, **Net Present Value, Internal Rate of Return and Benefit-Cost Ratio.**

Net Present Value. This criteria is based on the fact that because of inflation and risk, money received in the present is worth more than money received in the future. The net present value of an investment in a NAD system is the present value of the benefits of that system minus the present value of the costs of the system. This criteria is calculated over the entire 15 year life of the investment in this NAD cost benefit tableau. It is the amount that the farmer could pay for the opportunity of making the investment in a NAD system (in addition to the cost of the system) without being financially worse off.

Internal Rate of Return. This criteria is the rate of discount (interest rate) that makes the present value of the benefits of the NAD system equal to the present value of the costs of the system. It is the real rate of return the farmer can expect to earn on his investment. An **Internal Rate of Return** greater than the farmer's cost of capital indicates that the investment is a sound one and should be undertaken. The spreadsheet calculates the internal rate of return over the entire life of the investment.

Benefit-Cost Ratio. This ratio is simply the present value of the benefits of the NAD system divided by the present value of the costs of the system. A ratio of one or greater indicates that the investment is a sound one and should be undertaken.

V. SENSITIVITY ANALYSIS

The profitability results associated with each cost benefit analysis are dependent on the values of the technical parameters chosen. If these values are changed, the profitability of the NAD system analyzed will change. While this is to be expected, it is imperative that the user know how sensitive the results are to changes in the parameters. For many of the parameters entered in the cost benefit tableau, the user would enter his best guess based on his recollection of past conditions. Consequently, it is useful to know how sensitive the final profitability assessment is to the parameter values to reduce the risk of making an erroneous decision based on less than perfect information.

The effect of varying parameter values on the profitability of NAD systems may be determined using sensitivity analysis. This procedure essentially involves changing parameter values and observing how net present value, internal rate of return and the benefit cost ratio change over a range of values for that parameter. This may be accomplished in one of two ways. First, the user can change the value of the parameter in the cost benefit tableau and observe the change in the evaluation criteria. This can be done repeatedly for a range of values for a parameter. Alternatively, the user may create a sensitivity analysis table. It is recommended that this alternative be used by more expert users.

The one way sensitivity table has partially been developed in Columns B through E, beginning in row 136. Row 136 and 137 identifies the parameter which the sensitivity analysis applies. The title can be changed by pressing the F2 function key (edit key) when the cursor is in position B136 and B137 and typing in the correct title. Row 140 indicates the evaluation criteria for which the sensitivity analysis is to be done. Cell B140 is empty and is to remain blank, this is imperative to the operation of the analysis. In column B, beginning in row 141 enter the level of parameter over the range desired. Continue as far down column B as is necessary.

To calculate the evaluation criteria over the range of parameter values simply follow the quattro commands.[2] The commands are as follows:

1. Press /

2. Bring cursor down to 'Advanced' and enter.

3. Bring cursor down to 'What If' and enter.

4. Bring cursor down to '1 Variable' and enter.

5. Your are asked to enter the address of the block. For example, B140..E 145. The only part of the address that will change with testing of different parameters is the the final row of number, ie. E149 or E 150 etc..

6. The program will then ask you to indicate the input cell address. This is accomplished by moving your cursor to the appropriate row and column of the parameter you are analysing. For example, if you wish to run a sensitivity test on the price of canola, move the cursor to column D, row 25, and press enter. You will get a wait signal for moment while the computer calculates the results.

7. To see your table press escape until the menu is gone.

8. This procedure can be repeated as often as desired, but remember to clear the B column of any incremental changes from a previous parameter test that may not have been typed over when the new parameter increments were typed in. This is simply done by pressing the space bar and pressing enter.

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[2] Borland International. Quattro Users Guide, Sprint and Borland International: Scott Valley, California, 1987, pp 316-318.

APPENDIX 2

Sensitivity Analysis of Technical Parameters
Effect on NAD Profitability
Scenario 1

SCENARIO 1

TABLE A2.1

SENSITIVITY OF RESULTS TO CHANGES IN BARLEY PRICE

	NPV$	IRR%	BCR
85.00	3,508	0.13	1.16
90.00	3,646	0.14	1.16
95.00	3,784	0.14	1.17
100.00	3,922	0.14	1.18
105.00	4,060	0.15	1.18
110.00	**4,198**	**0.15**	**1.19**
120.00	4,474	0.15	1.20
130.00	4,750	0.16	1.21

TABLE A2.2

SENSITIVITY OF RESULTS TO CHANGES IN WHEAT PRICES

	NPV$	IRR%	BCR
130.00	3,512	0.13	1.16
140.00	3,855	0.14	1.17
150.00	**4,198**	**0.15**	**1.19**
160.00	4,541	0.16	1.20
170.00	4,883	0.16	1.22
180.00	5,226	0.17	1.23
190.00	5,569	0.18	1.25
200.00	5,912	0.18	1.26

TABLE A2.3

SENSITIVITY OF RESULTS TO CHANGES IN CANOLA PRICE

	NPV$	IRR%	BCR
260.00	3,505	0.13	1.16
270.00	3,851	0.14	1.17
280.00	**4,198**	**0.15**	**1.19**
290.00	4,544	0.16	1.20
300.00	4,891	0.16	1.22
320.00	5,584	0.18	1.25
350.00	6,623	0.20	1.30

TABLE A2.4

SENSITIVITY OF RESULTS TO CHANGES IN COMBINE OPERATING MARGIN

	NPV$	IRR%	BCR
50.00	3,864	0.14	1.17
55.00	3,947	0.14	1.18
60.00	4,031	0.15	1.18
65.00	4,114	0.15	1.18
70.00	**4,198**	**0.15**	**1.19**
75.00	4,281	0.15	1.19
80.00	4,364	0.15	1.20
85.00	4,448	0.15	1.20
90.00	4,531	0.16	1.20

TABLE A2.5

SENSITIVITY OF RESULTS TO CHANGES IN COMBINE CAPACITY

	NPV$	IRR%	BCR
8.00	5,125	0.17	1.23
9.00	4,610	0.16	1.21
10.00	**4,198**	**0.15**	**1.19**
11.00	3,860	0.14	1.17
12.00	3,579	0.14	1.16

TABLE A2.6

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROBABILITY OF INCREASED COMBINE USE

	NPV$	IRR%	BCR
0.10	1,905	0.10	1.09
0.15	2,669	0.12	1.12
0.20	3,433	0.13	1.15
0.25	**4,198**	**0.15**	**1.19**
0.30	4,962	0.16	1.22
0.35	5,726	0.18	1.26
0.40	6,491	0.20	1.29
0.50	8,019	0.23	1.36
0.60	9,540	0.25	1.43

TABLE A2.7

SENSITIVITY OF RESULTS TO CHANGES IN DISCOUNT FOR TOUGH WHEAT ($)

	NPV$	IRR%	BCR
3.50	3,774	O.14	1.17
5.00	3,947	0.14	1.18
6.00	4,077	0.15	1.18
7.00	**4,198**	**0.15**	**1.19**
8.00	4,319	0.15	1.19
9.00	4,440	0.15	1.20
10.50	4,621	0.16	1.21

TABLE A2.8

SENSITIVITY OF RESULTS TO CHANGES IN DISCOUNT FOR TOUGH CANOLA ($)

	NPV$	IRR%	BCR
10.00	3,863	0.14	1.17
12.00	3,997	0.14	1.18
14.00	4,198	0.15	1.18
15.00	**4,198**	**0.15**	**1.19**
16.00	4,265	0.15	1.19
18.00	4,398	0.15	1.20
20.00	4,532	0.16	1.20

TABLE A2.9

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROPORTION OF HARVEST FOR TOUGH/DAMP FOR WHEAT AND BARLEY

	NPV$	IRR%	BCR
0.05	3,192	0.15	1.14
0.10	3,695	0.14	1.17
0.15	**4,198**	**0.15**	**1.19**
0.20	4,701	0.16	1.21
0.25	5,204	0.17	1.23

TABLE A2.10

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROPORTION OF HARVEST TOUGH/DAMP CANOLA

	NPV$	IRR%	BCR
0.05	3,776	O.14	1.17
0.10	**4,198**	**0.15**	**1.19**
0.15	4,630	0.16	1.21
0.20	5,062	0.17	1.23

TABLE A2.11

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROBABILITY OF GRADE LOSS BARLEY AND WHEAT

	NPV$	IRR%	BCR
0.10	2,419	0.11	1.11
0.15	3,605	0.12	1.13
0.20	3,605	0.14	1.16
0.25	**4,198**	**0.15**	**1.19**
0.30	4,791	0.16	1.21
0.35	5,383	0.17	1.24
0.40	5,976	0.19	1.27

TABLE A2.12

SENSITIVITY OF RESULTS TO CHANGES IN DISCOUNT FOR WHEAT GRADE LOSS

	NPV$	IRR%	BCR
1.50	3,712	0.15	1.17
2.00	3,874	0.14	1.17
2.50	4,036	0.15	1.18
3.00	**4,198**	**0.15**	**1.19**
3.50	4,360	0.15	1.20
4.00	4,522	0.16	1.20
4.50	4,684	0.16	1.21

TABLE A2.13

SENSITIVITY OF RESULTS TO CHANGES IN DISCOUNT FOR CANOLA GRADE LOSS

	NPV$	IRR%	BCR
6.50	3,999	0.14	1.18
8.00	4,045	0.15	1.18
10.00	4,106	0.15	1.18
12.50	4,167	0.15	1.19
13.50	4,213	0.15	1.19
15.00	4,259	0.15	1.19
16.50	4,289	0.15	1.19

TABLE A2.14

SENSITIVITY OF RESULTS TO CHANGES IN REDUCED COMBINE LOSSES (%)

	NPV$	IRR%	BCR
1.00	992	0.08	1.04
1.50	2,996	0.12	1.13
1.00	**4,198**	**0.15**	**1.19**
2.00	4,999	0.17	1.22
2.50	7,002	0.21	1.31
3.00	9,005	0.24	1.40
3.50	11,009	0.28	1.49
4.00	13,012	0.32	1.58
4.50	15,015	0.36	1.67

TABLE A2.15

SENSITIVITY OF RESULTS TO CHANGES IN BASE WEIGHTLOSS DUE TO WEATHERING BARLEY AND WHEAT

	NPV$	IRR%	BCR
2.00	3,781	0.14	1.17
2.50	3,989	0.14	1.18
3.00	**4,198**	**0.15**	**1.19**
3.50	4,406	0.16	1.20
4.00	4,614	0.16	1.21

TABLE A2.16

SENSITIVITY OF RESULTS TO CHANGES IN EXCESSIVE HANDLING COST

	NPV$	IRR%	BCR
0.50	4,883	O.16	1.23
1.00	4,540	0.16	1.21
1.50	**4,198**	**0.15**	**1.19**
2.00	3,855	0.14	1.17
2.50	3,513	0.13	1.15

TABLE A2.17

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROBABILITY OF STORAGE LOSS

	NPV$	IRR%	BCR
0.25	3,703	0.14	1.17
0.50	**4,198**	**0.15**	**1.19**
0.75	4,692	0.16	1.21
1.00	5,186	0.17	1.23
1.25	5,681	0.18	1.25
1.50	6,175	0.19	1.28
2.00	7,164	0.21	1.32

TABLE A2.18

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROBABILITY OF INSECT LOSS

	NPV$	IRR%	BCR
0.25	3,703	0.14	1.17
0.50	**4,198**	**0.15**	**1.19**
0.75	4,692	0.16	1.21
1.00	5,186	0.17	1.23
1.25	5,681	0.18	1.25
1.50	6,175	0.19	1.28
2.00	7,164	0.21	1.32

APPENDIX 3

Sensitivity Analysis of Technical Parameters
Effect on NAD Profitability
Scenario 33

SCENARIO 33

TABLE A3.1

SENSITIVITY OF RESULTS TO CHANGES IN WHEAT PRICE

	NPV$	IRR%	BCR
130.00	(457)	0.03	0.95
140.00	(114)	0.05	0.99
150.00	**228**	**0.06**	**1.03**
160.00	571	0.07	1.07
170.00	914	0.08	1.11
180.00	1,257	0.09	1.15
190.00	1,599	0.10	1.19
200.00	1,942	0.11	1.23

TABLE A3.2

SENSITIVITY OF RESULTS TO CHANGES IN COMBINE OPERATING MARGIN

	NPV$	IRR%	BCR
50.00	(186)	0.04	0.98
55.00	(82)	0.05	0.99
60.00	21	0.05	1.00
70.00	**228**	**0.06**	**1.03**
75.00	331	0.06	1.03
80.00	435	0.07	1.05
85.00	539	0.07	1.06
90.00	642	0.07	1.08

TABLE A3.3

SENSITIVITY OF RESULTS TO CHANGES IN COMBINE CAPACITY

	NPV$	IRR%	BCR
8.00	591	0.07	1.07
9.00	389	0.06	1.05
10.00	**228**	**0.06**	**1.03**
11.00	96	0.05	1.01
12.00	(13)	0.05	1.00

TABLE A3.4

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROBABILITY OF INCREASED COMBINE USE

	NPV$	IRR%	BCR
0.10	(642)	O.03	0.92
0.15	(351)	0.04	0.96
0.20	(61)	0.05	0.99
0.25	**228**	**0.06**	**1.03**
0.30	518	0.07	1.06
0.35	837	0.08	1.10
0.40	1,098	0.09	1.13
0.50	1,679	0.11	1.20
0.60	2,259	0.12	1.27

TABLE A3.5

SENSITIVITY OF RESULTS TO CHANGES IN DISCOUNT FOR TOUGH WHEAT

	NPV$	IRR%	BCR
3.50	(195)	0.04	0.98
5.00	(13)	0.05	1.00
6.00	107	0.05	1.01
7.00	**228**	**0.06**	**1.03**
8.00	349	0.06	1.04
9.00	470	0.07	1.06
10.50	651	0.07	1.08

TABLE A3.6

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROPORTION OF HARVEST TOUGH/DAMP

	NPV$	IRR%	BCR
0.05	(361)	0.04	0.96
0.10	(66)	0.05	0.99
0.15	**228**	**0.06**	**1.03**
0.20	523	0.07	1.06
0.25	817	0.08	1.10

TABLE A3.7

SENSITIVITY OF RESULTS TO CHANGES IN PROBABILITY OF GRADE LOSS

	NPV$	IRR%	BCR
0.10	(826)	O.02	0.90
0.15	(475)	0.03	0.94
0.20	(123)	0.05	0.99
0.25	**228**	**0.06**	**1.03**
0.30	580	0.07	1.07
0.35	931	0.08	1.11
0.40	1,283	0.09	1.15
0.50	1,986	0.12	1.24

TABLE A3.8

SENSITIVITY OF RESULTS TO CHANGES IN DISCOUNTING FOR WHEAT GRADE LOSS

	NPV$	IRR%	BCR
1.50	(257)	0.04	0.97
2.00	(95)	0.05	0.99
2.50	66	0.05	1.01
3.00	**228**	**0.06**	**1.03**
3.50	390	0.06	1.05
4.00	552	0.07	1.07
4.50	714	0.08	1.09

TABLE A3.9

SENSITIVITY OF RESULTS TO CHANGES IN REDUCED COMBINE LOSSES

	NPV$	IRR%	BCR
1.00	(793)	0.02	0.91
1.50	(154)	0.04	0.98
1.80	**228**	**0.06**	**1.03**
2.00	438	0.07	1.06
2.50	1,122	0.09	1.13
3.00	1,760	0.11	1.21
3.50	2,398	0.13	1.29
4.00	3,037	0.15	1.36
4.50	3,675	0.17	1.44

TABLE A3.10

SENSITIVITY OF RESULTS TO CHANGES IN PERCENT BASE WEIGHT LOSS DUE TO WEATHERING, WHEAT

	NPV$	IRR%	BCR
2.00	(33)	O.05	1.00
2.50	97	0.05	1.01
3.00	**228**	**0.06**	**1.03**
3.50	359	0.06	1.04
4.00	490	0.07	1.06

TABLE A3.11

SENSITIVITY OF RESULTS TO CHANGES IN BASE PROBABILITY OF STORAGE LOSS

	NPV$	IRR%	BCR
0.25	(82)	0.05	0.99
0.50	**228**	**0.06**	**1.03**
0.75	539	0.07	1.06
1.00	850	0.08	1.10
1.25	1,160	0.09	1.14
1.50	1,471	0.10	1.18
2.00	2,093	0.12	1.25
2.50	2,715	0.14	1.32

TABLE A3.12

SENSITIVITY OF RESULTS TO CHANGES IN OPPORTUNITY COST OF CAPITAL

	NPV$	IRR%	BCR
0.03	(361)	0.04	0.96
0.04	228	0.05	0.99
0.05	**228**	**0.06**	**1.03**
0.06	523	0.07	1.06
0.07	817	0.08	1.10