An Economic Assessment of the **McLeod Harvest**

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Economic Setting

Small profit margins are forcing farmers to re-examine their assumptions about cropping agronomy, harvesting, and post harvest handling. Although the value of collecting chaff and weed seeds is proven, the additional equipment and operating costs in the past have been the limiting factors in the implementation of chaff collection systems.

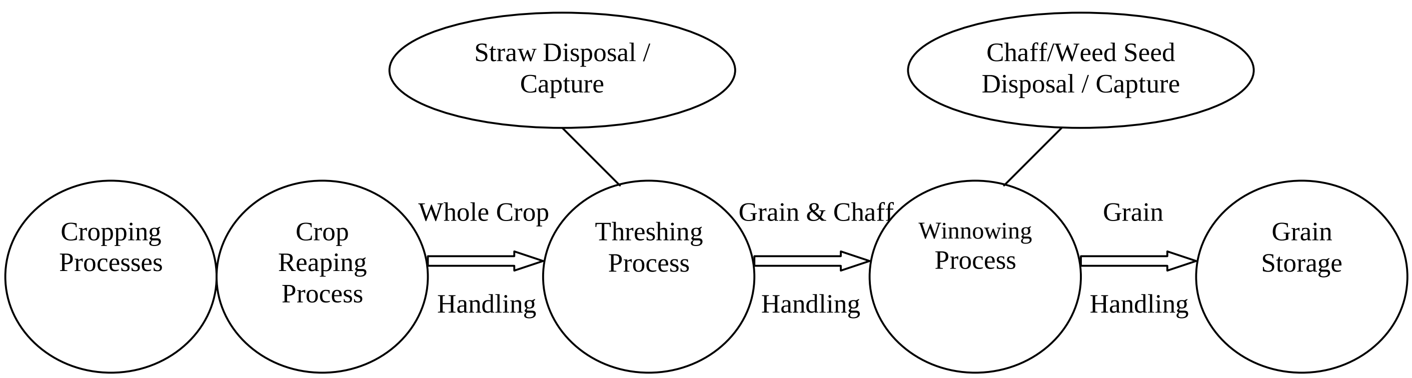
Increasing equipment and crop input costs together with years of low grain prices have forced farms to increase in scale to survive. Only the largest farmers in the range of 2,000 to 3,000 acres are able to purchase a new combine harvester. However, 80 percent of producers still manage farming operations of less than 2,000 acres.

In Canada, the 1996 census reported 328,667 combines on farms. Given average sales of 3,000 units per year, the effective life of this equipment would have to be 100 years to sustain this current inventory of equipment. Such an anomaly cannot be sustained indefinitely.

Re-engineering

While harvesting machinery may change, the basic processes that comprise crop harvesting remain the same. It is how these operations are organized that determines the economics of different harvesting machinery systems. Figure 1 illustrates the crop harvesting processes within the harvesting system.

Figure 1 – Crop Harvesting Processes



The binder/thresher system utilized manual labour for crop reaping. Threshing and *winnowing*[1] operations were combined into the threshing machine. All straw, chaff and weed seeds were collected by the stationary thresher in this system.

The introduction of the combine harvester reduced labour requirements by merging reaping, threshing and winnowing functions into a single piece of equipment. Savings were achieved by

[1] *Winnowing* refers to the removal of chaff, weed seeds, and other crop residue during the cleaning of grain.

minimizing the amount of material handled. The combination of functions into a single machine created design compromises. Harvested grain can contain 3 percent or more foreign matter, while weed seeds and chaff are awkward to collect.

The McLeod Harvest system employs two pieces of equipment instead of one to perform the functions of harvesting. Reaping and threshing processes are completed by the McLeod field unit, while the winnowing process is carried out at a stationary mill. Grain, chaff, weed seeds and other material (collectively known as graff) are collected by the field unit and transported by truck to a winnowing mill that is located near the grain bins. Straw is spread back onto the field or deposited in rows for subsequent bailing.

The winnowing mill cleans the grain, which is then put into storage or shipped to market. Chaff, crushed weed seeds and small kernels of grain (collectively known as millings) are piled separately and used as a source of livestock feed. The simple reorganization of these harvesting functions has a profound impact on the economics of grain farming.

Financial Analysis

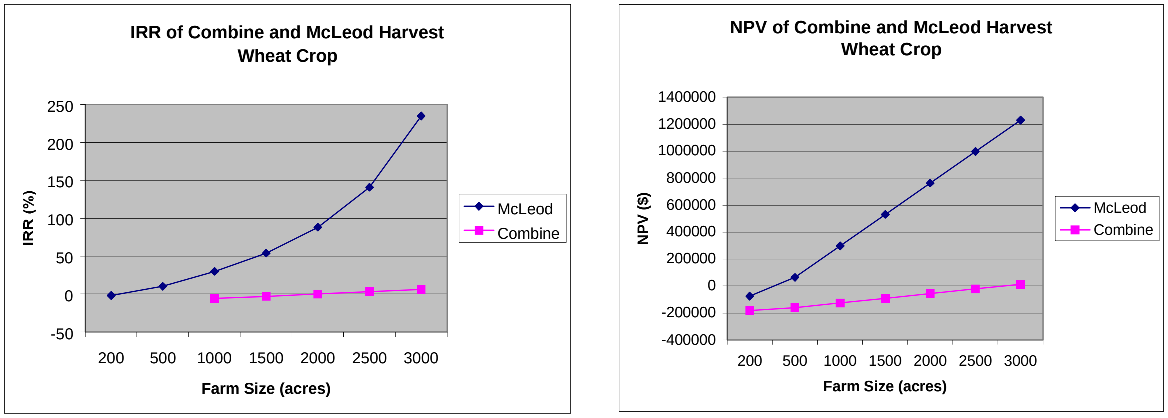
The economic assessment utilizes a benefit-cost (B/C) approach. A 15 year investment lifetime is used to determine the merits of investing in the McLeod Harvest versus the combine. The average price of a new combine is $216,000, compared to $192,000 for the McLeod Harvest system. Operating costs of the McLeod Harvest system are lower by $14.78/hour.

The economics of crop production are sensitive to acreage size, yield and the price of grain. At wheat yields of 40 bushels per acre and a farm price of $4.30 per bushel, the B/C analysis is calculated for farm sizes ranging from 200 to 3,000 acres[2]. The net present value (NPV) measures the return on investment in addition to the desired rate of interest[3]. Alternatively, the implied interest rate can be calculated as an internal rate of return (IRR).

As illustrated in Figure 2, the McLeod Harvest system shifts the harvesting processes to a higher production function. The internal rate of return and net present value of the McLeod Harvest are greater than the combine for all farm sizes under consideration. A farm as small as 500 acres could afford to purchase the McLeod Harvest at these prices, while even an operation of 2,000 acres would lose money on the investment in a traditional combine harvester.

[2] The reliability of these estimates diminishes after farm sizes of 1,500 acres. Data were not strictly collected for the operational feasibility in this size range.
[3] In this analysis, a 5 percent real (zero inflation) rate of interest is assumed.

Figure 2 – IRR and NPV of the Combine and the McLeod Harvest - Wheat Crop



Activity Based Costing

In total, the McLeod Harvest can increase a farmer's profit margin by $36.59/acre. This profit is influenced by reduced input costs (namely herbicides), and supplementary revenues from cleaned grain and salvaged crop residue. Collected chaff has the value of medium to high quality hay when utilized as cattle feed. An average chaff yield is estimated at 525 lbs./acre[4]. Using recent average hay prices, the value of chaff used for feed is $17.38/acre.

The McLeod Harvest system is designed to capture all grain, chaff, weed seeds and crop residue particles. Stationary machinery cleans grain more efficiently and reduces grain loss. The difference in grain loss between the combine and the McLeod Harvest system is worth $2.54/acre. The splitting of operations increases the cleaning efficiency of the McLeod Harvest system, which adds further economic value. Producing grain cleaned to export quality standards is worth an additional $0.67/acre.

The physical collection of weed seeds improves short term and long term weed management. Less herbicide and tillage is required to control grasses and volunteer crops. Chaff collection also limits the spread of weeds. As a result, significant savings can be obtained by precision application of patch sprays. An estimate of the agronomic savings of improved weed management in the McLeod Harvest system is $16.00/acre.

Operational and Environmental Implications

The McLeod Harvest handles approximately three to four times more material than the combine does. A simulation model is used to assess the impact of extra material handling on the labour and handling costs of the McLeod Harvest system. Barley and canola are included with wheat in the operational simulations to test the sensitivity of different crop types. A 600 bushel capacity

[4] Chaff yields can vary depending on grain yield, crop moisture level, and the type of threshing cylinder used (rotary or conventional).

McLeod Harvest is operationally feasible for hauling distances of up to 3 miles. For longer distances, larger truck sizes and equipment are likely to be more economic.

Environmental impacts are important, especially in light of the Kyoto Agreement on reducing greenhouse gas emissions. The McLeod Harvest substitutes electricity for diesel fuel for a major part of its power requirements. Less herbicide is required to be produced, distributed and applied. The avoidance of greenhouse gases in the production of livestock fodder is another possible gain. An extra head of cattle can be raised on McLeod Harvest millings for every fifteen acres of grain production.

Conclusion

Changes in input costs and technological improvements alter the economics of competing grain harvesting systems. This study concludes that the economics of the new McLeod Harvest system are superior to the incumbent combine harvesting system.

Farmers who adopt the McLeod Harvest can increase their profit margins by $36/acre. This is based on an analysis of wheat, but appears to apply to most grain and oilseed crops. In addition, the McLeod Harvest machinery has lower capital and operating costs than conventional combine harvesters. The analysis suggests that the McLeod Harvest could be the most important innovation to prairie agriculture since the breeding of canola.

1. INTRODUCTION

Technological improvement in grain harvesting has been one of the key achievements of mankind and is at the very base of civilization's advance. The invention of labour saving devices has lowered the cost of food production and improved the income of farmers. Over time, various systems of grain harvesting have come and gone. The scythe and flail gave way to the horse-drawn mechanical binder and steam-powered threshing machine. After 1945, rural out migration created serious labour shortages that made stationary threshing machines uneconomic. During the last half of the 20^{th} century, the combine harvester has come to epitomise modern agricultural systems.

Technological advance and changing input prices create opportunities to re-engineer systems. Combines have grown larger, faster, and more comfortable to operate, but their basic design is essentially unchanged. The combine harvester is a mature technology with few opportunities for further efficiency gains. However, the cost of this equipment is increasingly priced beyond the means of most farmers.

The McLeod Harvest is an alternative harvesting system to the combine[5]. It employs some combine technology, but re-organizes the operations into a two step harvest. First, collecting and threshing operations are performed by a tractor-powered field unit. The McLeod field unit direct cuts or collects the crop in a swath like the combine. Grain and weed material proceed through a threshing cylinder where straw is removed and returned to the field. The threshed but unseparated mixture of grain, chaff, weed seeds, leaves, small pieces of straw and other crop residue is transported to the stationary McLeod mill for winnowing and cleaning. This mixture of harvested material is referred to as *graff* throughout the remainder of the report.

Graff is dumped onto a receiving table that conveys this material into the mill. Cleaned grain is put into storage bins, while small or broken kernels and weed seeds are crushed and mixed with chaff to form *millings*[6]. Millings, which provide a source of ruminant livestock feed equivalent to medium to high quality forage, are stored in a pile that requires no further protection from the environment.

These two new terms, graff and millings, have been created to describe key products that are unique to the McLeod Harvest.

1.1 PURPOSE AND SCOPE

Economies of size are so pervasive in agriculture that most small and medium sized farmers require off farm income to maintain an acceptable standard of living. Table 1.1 shows the average net operating income by revenue class for Canadian farms in 1995 and 1996.

[5] Appendix A contains a description of McLeod Harvest Inc.

[6] *Millings* is a mixture of chaff, weed seeds, broken and small kernels, leaves and other crop residue produced by the mill. Screenings from the grain cleaning process are crushed and mixed with chaff to produce millings, which is used as animal feed.

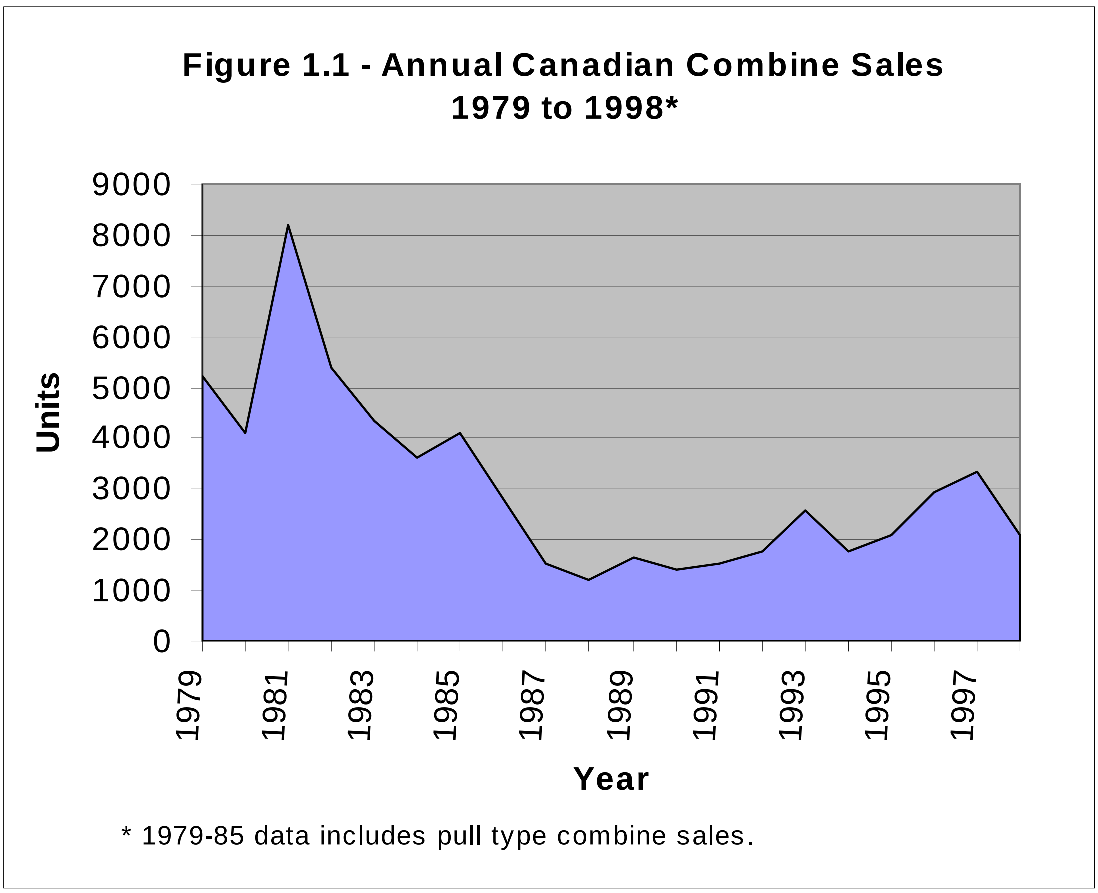
Table 1.1 – Net Operating Income by Revenue Class, Canada, 1995 and 1996

Farm Revenue		$10,000 to $24,999	$25,000 to $49,999	$50,000 to $99,999	$100,000 to $249,000	$250,000 to $499,999	$500,000 and over	All Farms
Net Operating Income	1996	(750)	4,475	13,818	34,031	67,835	168,801	23,977
	1995	(94)	5,435	15,573	35,759	66,643	152,006	23,561

Source: Agriculture and Agri-Food Canada (from Statistics Canada, Whole Farm Data Base)

The median farm income would be well below $20,000 because the largest 20 percent of farmers account for over 80 percent of farm sales. Net operating income is not the same as salary income. In addition to a farmer's labour, this income must compensate for investment in land and equipment, and the business risk of operating the farm.

Low levels of income restrict capital expenditure on farm equipment purchases. The combine is the most expensive piece of farm machinery, with an average retail price of $216,000[7]. Its high cost leads to a pent up demand that creates erratic sales from year to year. Figure 1.1 illustrates the annual sales of combines in Canada since 1979.



[7] Weighted average retail price of models utilized on the Canadian Prairies.

Combine sales largely follow agricultural commodity prices. Low commodity prices in 1998 caused sales to revert back to a more normal level. Combine sales averaged 1,931 units per year for the period of 1986 to 1996.

Combine replacement rates are far below sustainable levels. Table 1.2 presents the retail sales of combines in both Canada and the United States for each of the last 5 years.

Table 1.2 – Retail Combine Sales in Canada and The United States

	1994	1995	1996	1997	1998
Canada	1,781	2,085	2,950	3,322	2,082
United States	8,499	9,194	9,032	9,639	10,396

Sources: Canada – Canadian Farm and Industrial Equipment Institute
United States – Equipment Manufacturers Institute

The 1996 Canadian Farm Census reports 328,667 combines in Canada. After taking custom combining into consideration, the three Canadian prairie provinces account for about 220,000 combines, or 66% of the Canadian market. If Canadian prairie farmers purchase 2,000 combines annually, the effective life of this equipment would have to be 100 years to sustain the current inventory of equipment.

The situation is similar in the United States. Grain operations are reported on just over 1,000,000 of the 2,000,000 farms in the United States. Taking into consideration custom combine operators and farms that employ combines in operations other than grain farming (e.g. cotton), the replacement rate still remains unrealistically low. With U.S. combine sales of 10,000 units/year, the replacement rate is well below the level required to update machinery at reasonable intervals.

If the useful lifetime of a combine is only 15 to 20 years, how can this variation exist? Investment in new combine harvesters has been limited to only the largest revenue class of producers. In the short run, small and medium sized farmers have continued to use existing machinery despite its obsolescence, and hope for grain prices that justify and enable newer combines to be purchased[8].

Depressed farm incomes have forced farmers to question every aspect of their operation. Farmers recognize the doubtful economics of a combine investment; the problem is they have had no alternative harvesting system to consider. A system that lowers the capital cost of harvesting equipment and provides better profit margins on crops deserves consideration. This report analyzes the McLeod Harvest and provides an assessment of this new technology relative to the combine harvester.

The combine and the McLeod Harvest compete directly on equipment costs, but also compete on efficiency of operations. The pressure to thresh a large amount of grain in a time limited

[8] Anecdotal evidence suggests the use of combines that are 30 years and older. Reliability, efficiency, repair costs, and spare parts availability become a real issue at this stage of operation.

harvesting season has forced many compromises on the design of the combine harvester. In order to increase speed, the combine returns almost all chaff and weed seeds back to the field. Spreading of weed seeds by the combine forces farmers to use more herbicides to control weeds. Like the stationary thresher, the McLeod Harvest reduces herbicide needs by collecting and removing weed seeds with the grain harvest.

Environmental impacts of technology may not sway commercial decisions in the short run, but this will change as international agreements and regulations become more stringent. A complete environmental analysis is beyond the scope of this report; however, the potential impact on soil fertility, energy consumption and chemical use is described.

1.2 OBJECTIVES AND METHOD OF ANALYSIS

No competitive alternative has seriously challenged the combine harvester for the past 50 years. This report examines the costs, benefits, and operational challenges of the McLeod Harvest versus the combine. The report has three objectives.

(i) Prepare the McLeod Harvest and combine harvester capital budgets and compare their return on investment.

(ii) Examine the positive and negative externalities of the two systems to analyze and quantify economic benefits.

(iii) Compare labour, transportation and material handling to evaluate the total costs of each system.

The scope of the investigation considers the specifications of the McLeod Harvest equipment and a new combine harvester. As with any new technology, sources of information on machinery operations and issues are limited to test data, secondary data sources and consultation with experts. Operational analysis is undertaken on the trucking implications of harvesting graff. The research relies on data collected from the operations of the McLeod Harvest equipment prototypes. Prototype equipment performance may be better or worse than the test data, but provides a baseline for the economic analysis[9].

Wherever applicable, the economic analysis relies on independent testing of the McLeod Harvest conducted by researchers at the University of Manitoba and University of Saskatchewan. Animal Science experts were consulted on the nutritional value of millings and the benefits of chaff collection. Plant Science experts were consulted on the implications of chaff collection and weed management. Finally, relevant secondary published sources on prices, operations, and testing were also examined[10].

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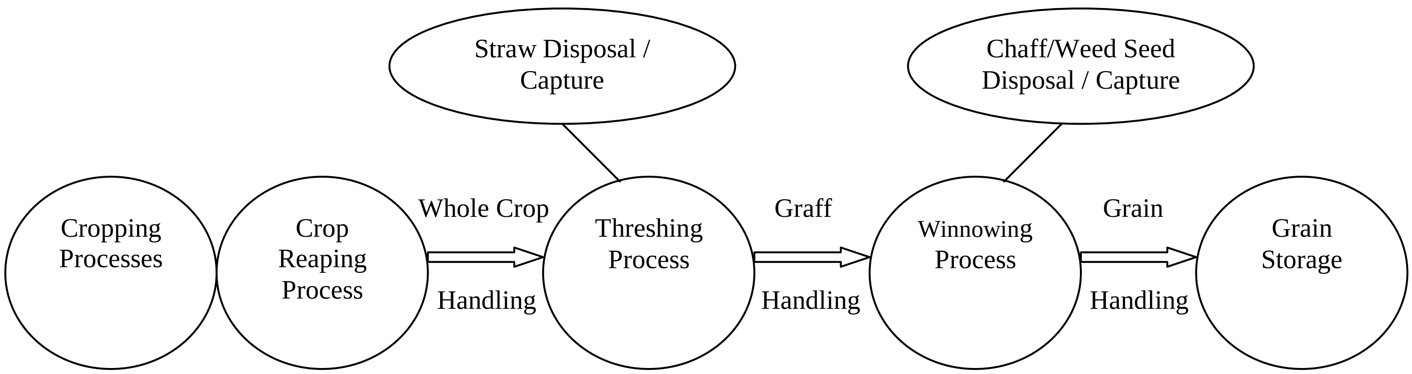
[9] All assumptions will be tested by commercial application. None of the mechanical challenges seem to pose large barriers (the assumption is that everything works as designed).

[10] Sources included information on chaff collection, chaff value, farm income, weed control, grain loss, etc. See the *References* section at the end of the report.

2. COMPARATIVE HARVESTING SYSTEMS

Harvesting machinery and technology continues to change. However, the basic operations of harvesting must be integrated into each type of new harvesting equipment. The processes involved in crop harvesting are presented in Figure 2.1.

Figure 2.1 – Crop Harvesting Processes

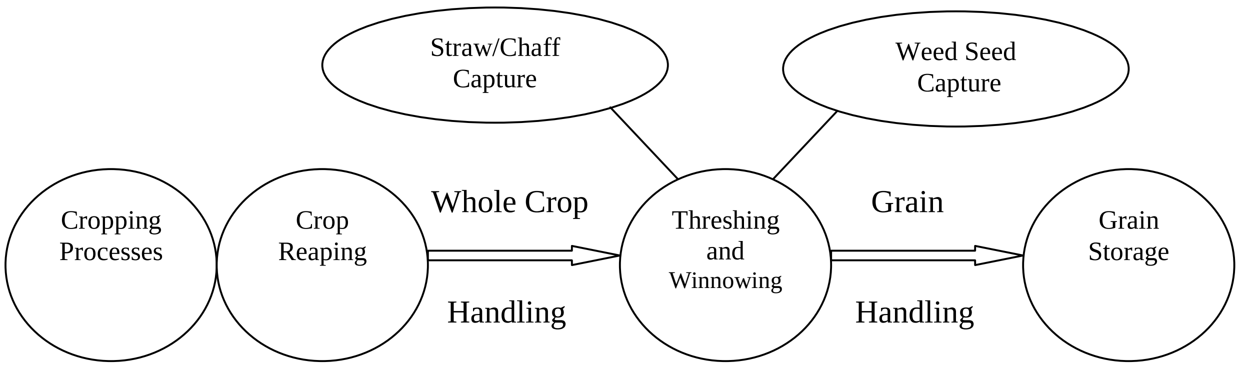


Crop harvesting processes are explained as follows. The crop is cut, dried and collected so that threshing can take place. Once the crop is threshed, grain and other material such as chaff and weed seeds (graff) are transferred to a winnowing process, while the straw is discarded. The winnowing process separates the chaff, weed seeds and other material from the grain. Finally, the grain must be conveyed to a storage facility. Whether the straw, chaff, weed seeds and other materials are captured for use, or simply spread on the field, depends on the costs and configuration of the system.

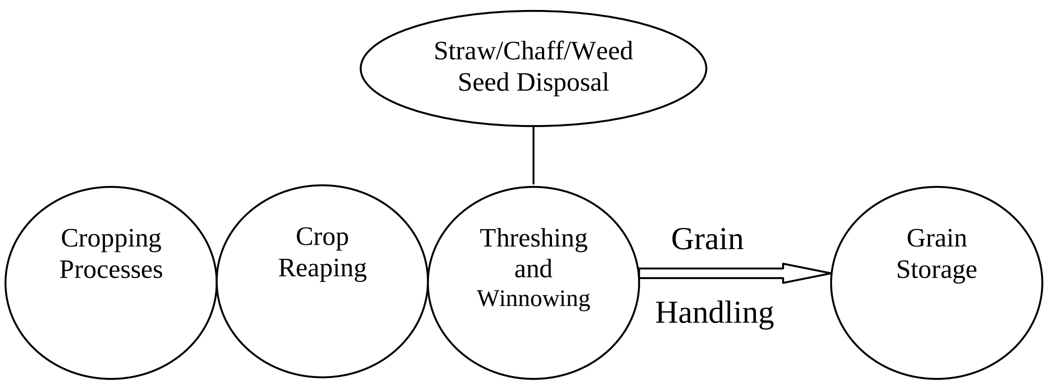
The harvesting processes cannot be eliminated, but they can be shifted or combined in various ways. The three most recent harvesting systems, the binder/threshing system, the combine, and the McLeod Harvest, simply restructure these processes. Figure 2.2 depicts the differences in organization of harvesting processes by the binder/threshing machine, the combine, and the McLeod Harvest.

Figure 2.2 – Crop Harvesting Processes of the Binder/Threshing Machine, the Combine, and the McLeod Harvest

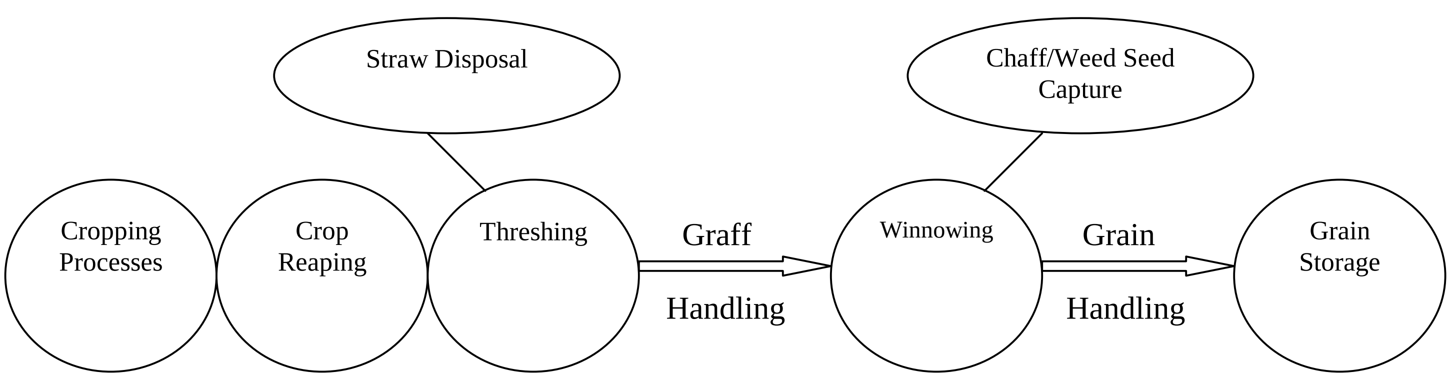
BINDER/THRESHING MACHINE



COMBINE



McLEOD HARVEST



The binder/threshing system minimized crop residue disposal, but maximized material handling. All crop material, including straw, was transported to the stationary thresher, which separated the straw and winnowed the grain from the chaff and weed seeds. Straw, chaff and weed seeds were captured for use in the livestock enterprise of the farm.

The combine minimizes material handling by amalgamating crop reaping, threshing, and winnowing functions into a single mobile field unit. In doing so, however, crop residue disposal is maximized. All chaff, weed seeds, and straw is discarded onto the field; the combine cannot capture the benefits associated with crop material collection.

The McLeod Harvest represents a mixed system. Material handling is less than the binder/threshing system, but greater than the combine. The McLeod field unit collects all crop residue except straw. Crop residue disposal of the McLeod Harvest is greater than the binder/threshing system, but less than the combine. Chaff is used as a source of livestock feed, and weed seeds are mechanically removed from the field.

Crop management is rarely thought to be related to harvesting. However, the frequency of tillage and level of weed management are influenced by the type of harvesting operation chosen. Depending on the chaff spreading characteristics of the harvesting operation in question, tillage operations and herbicide sprays may be increased or decreased as a result.

Figure 2.3 outlines the harvesting activities by function for each of the harvesting methods. The operations of each system are compared using different functions from field management to export quality cleaning. This diagram illustrates the discrepancies in organization of each harvesting method that culminate in different total costs.

Figure 2.3 – Comparison of Harvesting Activities by Function

Functions	**The Binder/Stationary Threshing Machine**	**The Combine Harvester**	**The McLeod Harvest**
Field Management	- extensive cultivation	- post emergent herbicide application - minimal cultivation - perennial herbicide application	- minimal cultivation - perennial herbicide application
Crop Reaping	- mechanical cutting and tying of sheaves - manual stoking of sheaves	- swather cut and sun dried or - desiccant application (optimal) and direct cut	- swather cut and sun dried or - desiccant application (optimal) and direct cut
Threshing	- manual feeding of sheaves to a stationary thresher on farm/field	- mobile thresher on field	- mobile thresher on field
Material Handling	- manual loading of sheaves on wagons drawn by horses or tractors	- mechanical transfer of grain by augers to trucks for transport	- mechanical transfer of graff to trucks for transport
Winnowing	- combined with stationary thresher	- combined with mobile thresher	- specialized stationary mill
Export Cleaning	- off-farm, or specialized grain cleaners	- off-farm, or specialized grain cleaners	- combined with stationary mill

2.1 THE COMBINE

Field Management

Farmers have come to depend on chemical herbicides to control weeds because the combine is unable to prevent their return to the field. In addition, the combine is an effective spreader of weed seeds, increasing the size of weed patches. Tillage operations or applications of herbicides are subsequently increased to control weeds.

Crop Reaping and Threshing

The specific operations of different combine models may vary, but the basic operations and functions remain the same. The combine collects the crop from a windrow using a pick up header, or the crop can be direct cut. The feeder conveyor delivers the crop from the header to the threshing cylinder, where it is threshed against the concave. A beater directs grain through the beater grate and moves the straw to the straw walkers. An upper tailings auger directs unthreshed grain back to the threshing cylinder.

Winnowing

Straw walkers shake grain from the straw, and the straw is discarded out the back of the combine. Grain and chaff fall on grain augers that lead to the cleaning shoe. The cleaning fan blows away chaff as grain falls to the chaffer and sieve, both components of the cleaning shoe. The clean grain auger sends grain to an elevator, which carries grain to the hopper. The lower tailings auger conveys unthreshed grain to the upper tailings auger, which carries grain back to the threshing cylinder for rethreshing.

Material Handling

The combine cleans grain and transfers it by augers to the truck for transport. The combine cannot salvage other crop residue, except by separate, relatively inefficient means. Leaving chaff on the field creates fertilizer placement and stand establishment problems associated with chaff windrows. The most popular method of chaff collection is using a chaff wagon towed behind a combine. Once the wagon is filled with chaff, it is dumped onto the field. Craig (1988) reports that chaff collection costs range from $21.50 – $49.00 per tonne depending on crop yields and the method of calculating machinery costs. The main cost of chaff collection is transport. Returning to pick up the light, voluminous chaff is an extra and costly step.

Export Cleaning

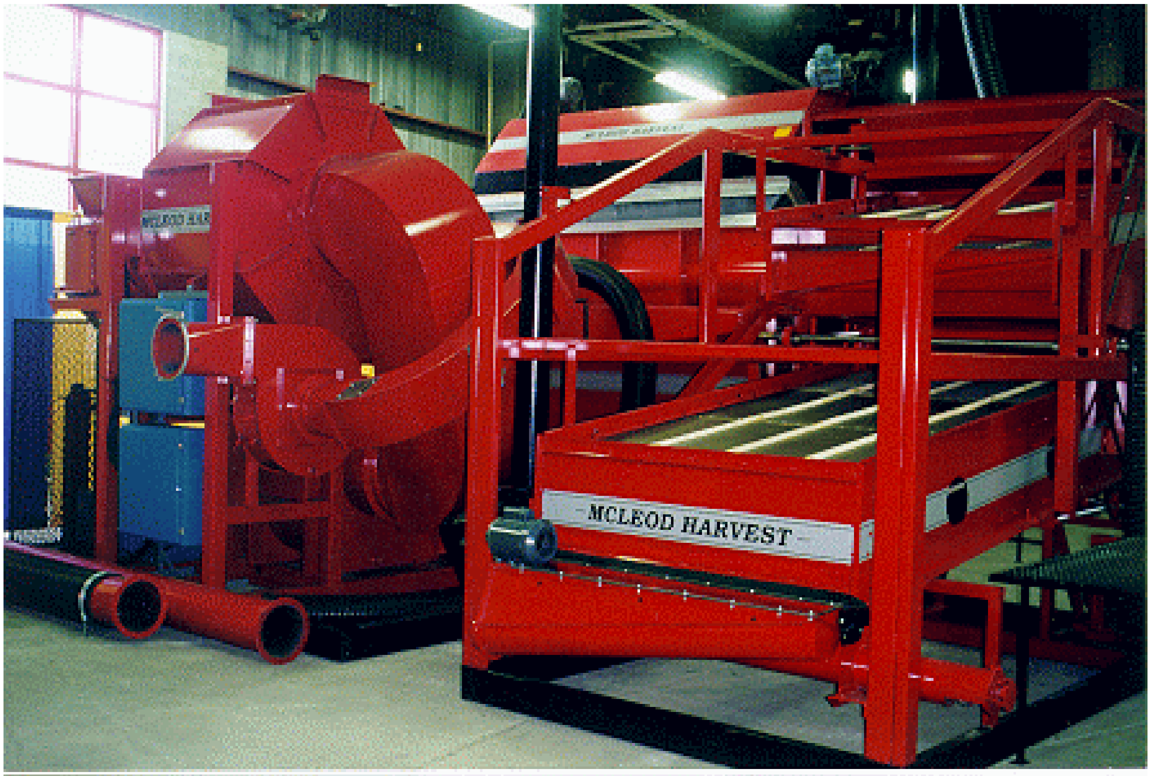
The combine produces a final grain product with some degree of dockage (between 1 and 3%). The confines of the combine body reduce cleaning efficiency. Export quality clean grain at the farm gate can only be obtained with a further yard based cleaning system.

2.2 THE McLEOD HARVEST

The McLeod Harvest is a re-engineering of the harvesting operation. Two pieces of equipment have been specifically designed to handle graff. Utilizing two pieces of equipment instead of one, the McLeod Harvest captures economies of specialization and division of labour gains that the combine cannot attain.

THE FIELD UNIT

THE MILL



Field Management

The McLeod Harvest reduces the number of herbicide applications required to control weeds. By gathering graff, weed seeds are physically collected and removed from the field. Patch based spraying can now be employed, as weed seeds are mechanically collected and patches contained. Herbicide applications are not entirely eliminated, because early maturing weeds, weeds that spread by roots, and perennial weeds still require herbicidal control.

Crop Reaping

Field reaping is performed by a specially designed harvester. Powered by a tractor, the McLeod field unit is attached via a hydrostatic swing hitch. This hitch is designed to swing out on either side of the tractor, with a 270 degree swing capacity. The driveline for the field unit is completely enclosed within the hitch. Either a straight cut or pick up header can be mounted on the field unit to collect the crop.

Threshing

The crop is conveyed through the feeder housing from the header to a specially designed conventional threshing cylinder. The cylinder threshes grain against the concave using a customized rasp bar system. The beater directs straw to shortened straw walkers, which shake grain from the straw. The beater also directs graff down to an auger bed, which carries the material to two graff elevators. Graff undergoes no further separation in the field.

The threshing operations of the McLeod Harvest cause less soil compaction than a comparable combine. The field unit is lighter, and weight is spread over three axles including the tractor. The McLeod Harvest works better in wet fields through the improved towing and traction capability of a tractor. Field speed is also expected to increase due to the elimination of shoe loss experienced by the combine.

Material Handling

Graff is conveyed by dual graff elevators, one on each side of the field unit, to a 600 bushel tank located on top of the threshing cylinder. A bin leveling auger is used to distribute graff evenly over the tank.

A high volume auger is used to unload graff from the field unit into the truck. This horizontal/vertical auger is designed to swing out to both sides of the field unit to facilitate unloading. The auger is sized for a 3 minute unloading time. Graff agitation devices are used to prevent bridging and assist unloading.

Efficient system coordination requires an equal flow capacity through each node of the network. The mill cleaning rate must be such that it can process the 600 bushel load before the next shipment arrives. Depending on the crop, there is approximately three to four times the material handled with the McLeod Harvest. Therefore, the storage capacity of the McLeod Harvest must be 3 times greater to match the harvesting capacity of the combine. This does not have a significant impact on equipment costs. The extra space obtained by eliminating the sieves, fans and cleaning shoe is filled with empty space, which has low marginal costs.

Graff is unloaded from the harvester tank into a truck and transported to the mill. At the farmstead, the truck's tailgate is opened and the entire load is dumped on a receiving table that feeds the winnowing mill.

Graff appears to flow easily while in a fluidized or moving state. When flow is disrupted, graff loses its fluidization characteristics and bridging and plugging ensue. Entry points into devices and conveyors are particularly prone to plugging. Agitation is required at transition points to prevent bridging. The unloading agitator on the field unit and tilting receiving table of the mill are two innovations that the McLeod Harvest employs to prevent problems associated with handling graff.

Winnowing and Export Cleaning

Once all the graff is unloaded, the receiving table of the mill is tilted using hydraulics to improve graff flow towards the conveying system. The conveying system carries graff to the top of a drop-type, vertical aspirator. The aspirator utilizes a closed centrifugal air system to remove chaff. Chaff is blown out of the mill to the outdoor millings pile.

The grain drops through the aspirator, and is augured to the screening system. Two sets of screens and forced air are used to remove foreign material such as weed seeds, small and broken kernels, small pieces of straw, rocks, and dirt. Clean grain is collected separately and augured into storage. Screenings are augured to the rolling mill, where weed seeds and other crop residue are crushed. Densified screenings are mixed with chaff, and the closed-air system blows the material to the outdoor millings pile.

The mill is powered by the new Written-Pole motor, which operates on single-phase 220-volt electrical service[11]. This 40-hp motor operates efficiently with auxiliary drives requiring an additional 20 hp.

The mill is fully automated, equipped with sensors that shut down the entire system should problems arise. Located at ground level, it is simple and easy to access and repair. The mill's stationary nature increases it useful economic life. The cleaning system is more efficient, using cleaning screens that are 1.7 times larger than the combine. The larger screens and increased airflow enable the mill to clean grain to minimal dockage levels.

In addition to cleaner grain, farmers capture the millings that consist of crushed screenings product and chaff. The texture of millings is such that it adheres to itself, reducing its susceptibility to being blown by the wind. Natural weathering causes the surface of the millings pile to cake. This crusting effect protects the pile from moisture penetration. A front-end loader can be used to move the millings pile as needed, and to feed cattle during the winter.

3. BENEFIT-COST ANALYSIS

The benefit-cost (B/C) analysis is an objective method to determine the advantages of alternative investments, in this case the combine versus the McLeod Harvest. The steps involved in a B/C analysis are: (1) list all of the benefits and costs, and any positive and negative externalities associated with the entire life of the project; (2) monetize all benefits and costs; (3) discount to the present value all benefits and costs that are flows over time by use of an appropriate rate of discount. Care was taken to avoid double counting any benefits or costs associated with a given investment. All values are expressed in "real" (non-inflationary) terms. Interest on borrowed funds and depreciation are excluded.

[11] The development of the Written-Pole motor is a critical feature of the McLeod Harvest. Prior to the Written-Pole motor, farms would have had to install three-phase power (estimated cost $25,000) in order to operate a 40-hp motor. Electricity production contributes less greenhouse gases and is less expensive than diesel fuel.

The B/C analysis assumes the purchase of a new combine and McLeod Harvest. Equipment costs include capital and operating costs. Internal rates of return (IRR) and net present values (NPV) are calculated for both types of harvesting equipment for 500, 1,000, and 2,000 acre farms over a 15 year period. Wheat, the principal crop of Western Canadian farmers, is the only crop used in the calculation of IRR and NPV. No attempt is made to account for the tax implications of these alternative investments because the situation for each farmer is too unique.

3.1 COMPARATIVE CAPITAL AND OPERATING COSTS

The equipment costs of the McLeod Harvest consist of a field unit, a mill, the attributed use of a tractor, and truck box modifications if required. The combine harvesting system consists solely of a self-propelled combine.

System coordination requires the matching of capacities across all system components. The field unit is designed with a 600 bushel tank to accommodate the larger volume of graff produced. It has been recognized that more Canadian prairie farmers are purchasing diesel tandem axle trucks in place of single axle ones. As a result, a Ford 8000 or an International 4900 diesel tandem axle truck with a 600 bushel box is used for both harvesting systems.

Examination of the optimal system capacity is conducted in *Chapter 5 – Operational Research.* This research concludes that the 600 bushel tandem axle truck most farmers now purchase is sufficient to handle the increased volume of graff produced by the McLeod Harvest. As a result, identical trucking methods facilitate the exclusion of trucking costs from modal comparison.

Table 3.1 presents the machinery specifications and costs of the components of the McLeod Harvest and the combine.

Table 3.1 – Machinery Specifications of the Components of the McLeod Harvest and Combine

McLeod Harvest Cost Calculations	*Tractor*	*Field Unit*	*Mill*	*Combine*
a) Average retail price	$ 125,000	$ 80,000	$ 85,000	$ 216,000
b) Accumulated hours	0 hr	0 hr	0 hr	0 hr
c) Economic life	15 yr	15 yr	25 yr	15 yr
d) Value attributed to harvest	20 %	100 %	100 %	100 %
e) Real interest rate	5 %	5 %	5 %	5 %
f) Annual use, acres	-	1,000 ac	-	1,000 ac
g) Field Capacity	-	6.7 ac/hr	-	6.7 ac/hr
h) Annual use, hours	750 hr	150 hr	150 hr	150 hr
i) Power Requirements	170 hp	-	60 hp	260 hp
j) Fuel Type	Diesel	-	Electric	Diesel

Capital Costs

The price of combines can exceed $350,000. This report assumes a 260 hp combine with a weighted average retail price of $216,000[12].

The equipment costs of the McLeod Harvest entail the field unit, mill, the attributed use of a tractor, and truck modifications. McLeod Harvest Inc. expects the introductory retail price of the field unit to be $80,000, and the price of the mill to be $85,000. The cost of the equipment is reasonable, but needs to be produced at scale to reach these costs. For the purpose of this analysis, only the initial retail price is considered.

Included in the equipment cost calculations of the McLeod Harvest is the attributed use of a tractor. A tractor with PTO power requirements of 170-hp would be sufficient to power the field unit. The average retail price of a 170-hp tractor is approximately $125,000. The equipment costs attributed are based on their contribution to harvesting as a percentage of overall annual activities. An attributing factor of 20% and tractor costs of $25,000 are incorporated into the McLeod Harvest system[13].

If a truck capacity of less than 600 bushels is employed, then height can be added to the sides of the truck to accommodate the increased volume handled. Adding a foot of height to the sides of the truck box would increase hauling capacity by about 100 bushels, at a cost of approximately $2,000. This increase in truck size is included in the capital cost analysis of the McLeod Harvest system due to the possibility of necessary truck box modifications. Existing truck suspensions are adequate to handle the increased load due to the low density of graff material.

The total equipment costs for the McLeod Harvest are substantially lower than that of the combine as shown in Table 3.2. Equipment costs are $216,000 for the combine and $192,000 for the McLeod Harvest. Costs savings of the McLeod Harvest are $24,000 or 11%.

Table 3.2 – McLeod Harvest vs. Combine Equipment Costs

Equipment	*Costs*	*Total Costs*
Combine		**$ 216,000**
McLeod Harvest		
Field Unit	$ 80,000	
Mill	$ 85,000	
Tractor	$ 25,000	
Truck Modification	$ 2,000	
Total		**$ 192,000**
Equipment Savings		**$ 24,000**

[12] Weighted average retail price of models utilized on the Canadian Prairies.
[13] Since this tractor is available to most farms and not an incremental cost, farmers may choose to discount this item.

Operating Costs

The methodology for determining the operating costs of both the McLeod Harvest and the combine is presented in *Appendix B – Costs Estimation*. Hourly operating costs are based on repair and maintenance (R&M), fuel and lubricant (F&L), and labour costs. Estimated hourly operating costs for both the McLeod Harvest and the combine are presented in Table 3.3.

Table 3.3 – Estimated Hourly Operating Costs of the McLeod Harvest and Combine

Estimated Operating Costs	*McLeod Harvest*			*Combine*
	Tractor	*Field Unit*	*Mill*	
6. Lifetime hours, % R&M of price	11,250 hr. 67%	2,250 hr. 45%	3,750 hr. 40%	2,250 hr. 45%
7. R&M per hour	$ 7.44/hr.	$ 16.00/hr.	$ 9.07/hr.	$ 43.20/hr.
8. F&L per hour	$ 13.39/hr.	-	$ 3.00/hr.	$ 20.48/hr.
9. Labour per hour	$ 11.75/hr.	-	-	$ 11.75/hr.
Total Operating Costs	(32.58+16.00+12.07)	**$ 60.65/hr.**		**$ 75.43/hr.**

Hourly operating costs are estimated at $75.43/hr. for the combine and $60.65/hr. for the McLeod Harvest. Operating savings of the McLeod Harvest are 20% or $14.78/hr. Repair and maintenance savings of $10.69/hr. are a result of longer lifetime of system components, lower R&M percentage of retail price, and lower capital costs. Fuel and lubricant savings of $4.09/hr are gained through lower horsepower requirements and the use of the electricity in the mill.

An analysis of annualized fixed costs and total costs of the McLeod Harvest is also contained in *Appendix B – Costs Estimation*.

3.2 PRIVATE BENEFITS

Private benefits are the revenues captured by the owner of an asset. Some investments create other benefits and costs that are not captured by the owner; these are discussed later in *Section 3.4 – Externalities and Public Benefits*. The private benefits of the combine and the McLeod Harvest are identified and quantified in this section.

The combine and the McLeod Harvest generate benefits through the collecting, threshing, and separation of grain in the harvesting of crops. These benefits are generalized as the value of grain harvesting. Equal values of grain harvesting are used for both the combine and McLeod Harvest. These values are derived from the revenues received from wheat minus its production costs. A full explanation of how the value of grain harvesting is derived is presented in *Appendix C – IRR and NPV Calculations.*

The McLeod Harvest creates additional benefits in its field operations. The main benefits include improved weed management and the use of graff as a source of livestock feed. Other benefits include lower levels of grain loss and dockage. These field benefits have been quantified in *Chapter 4 – Field Benefits*. Table 3.4 illustrates the private benefits created by the combine and the McLeod Harvest.

Table 3.4 – Private Benefits

	Value of Grain Harvesting	*McLeod Benefits*			*Total Benefits*
		Weed Benefits	*Chaff Benefits*	*Other Benefits*	
McLeod Harvest	$18.00/acre	$16.00/acre	$17.38/acre	$3.21/acre	**$54.59/acre**
Combine	$18.00/acre	-	-	-	**$18.00/acre**

3.3 INTERNAL RATE OF RETURN AND NET PRESENT VALUE

The internal rate of return (IRR) represents the annualized benefit earned by an investment over the course of its life[14]. The net present value (NPV) is the value of all benefits and costs discounted at a chosen cost of capital. Typically, an investor chooses the target rate of return (real interest rate) and sums the stream of discounted benefits and costs. If the NPV is positive, the target rate of return is achieved. Any NPV above zero is an extra gain to the investor beyond their targeted return.

The IRR and NPV are calculated for the combine and the McLeod Harvest over their economic lifetime of 15 years. Cash inflows are the private benefits, which include the value of grain harvesting and field benefits. Capital and operating costs are the cash outflows used in these investment analysis methods. The cash inflows and outflows used to calculate the IRR and NPV of these two harvesting methods are illustrated in *Appendix C – IRR and NPV Calculations*. A real interest rate of 5% is used as the discount rate for calculating IRR and NPV. An assumption in calculating these figures is that no more labour or trucking is required for the McLeod Harvest. The IRR and NPV values for different farm sizes are listed in Table 3.5.

Table 3.5 – IRR and NPV of the Combine and the McLeod Harvest

		Combine	**McLeod Harvest**
500 acres	IRR	-	10%
	NPV	($160,313)	$64,843
1,000 acres	IRR	-	30%
	NPV	***($125,625)***	$297,876
2,000 acres	IRR	0.4%	88%
	NPV	($56,226)	$763,954

For the 500 acre farm, the IRR for the combine is negative because the discounted cash inflows never add up to the initial cash outlay. However, the McLeod Harvest has an IRR of 10% due to the field benefits it generates and lower operating costs. The NPV of the combine is ($160,313) for a 500 acre farm, while the McLeod Harvest has a positive NPV of $64,843. A farmer with

[14] Technically, the IRR is the discount rate that can be applied to the stream of benefits and costs over the lifetime of the investment, which causes the net present value of the benefits minus costs to equal zero. Care must be taken in the interpretation of the IRR. The calculation assumes that the annual benefits can be invested at the discount rate. For a very high IRR, this assumption may be unrealistic.

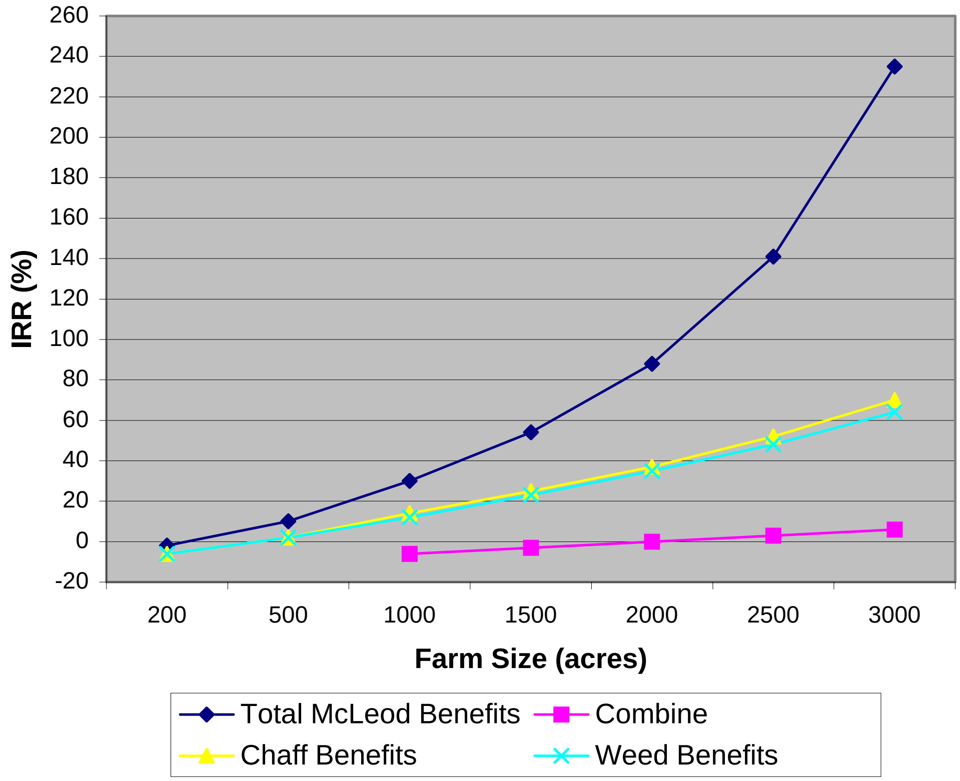
500 acres could earn 5 percent (plus inflation) on an investment in the McLeod Harvest, plus receive the equivalent of $64,843 on the first day of the investment.

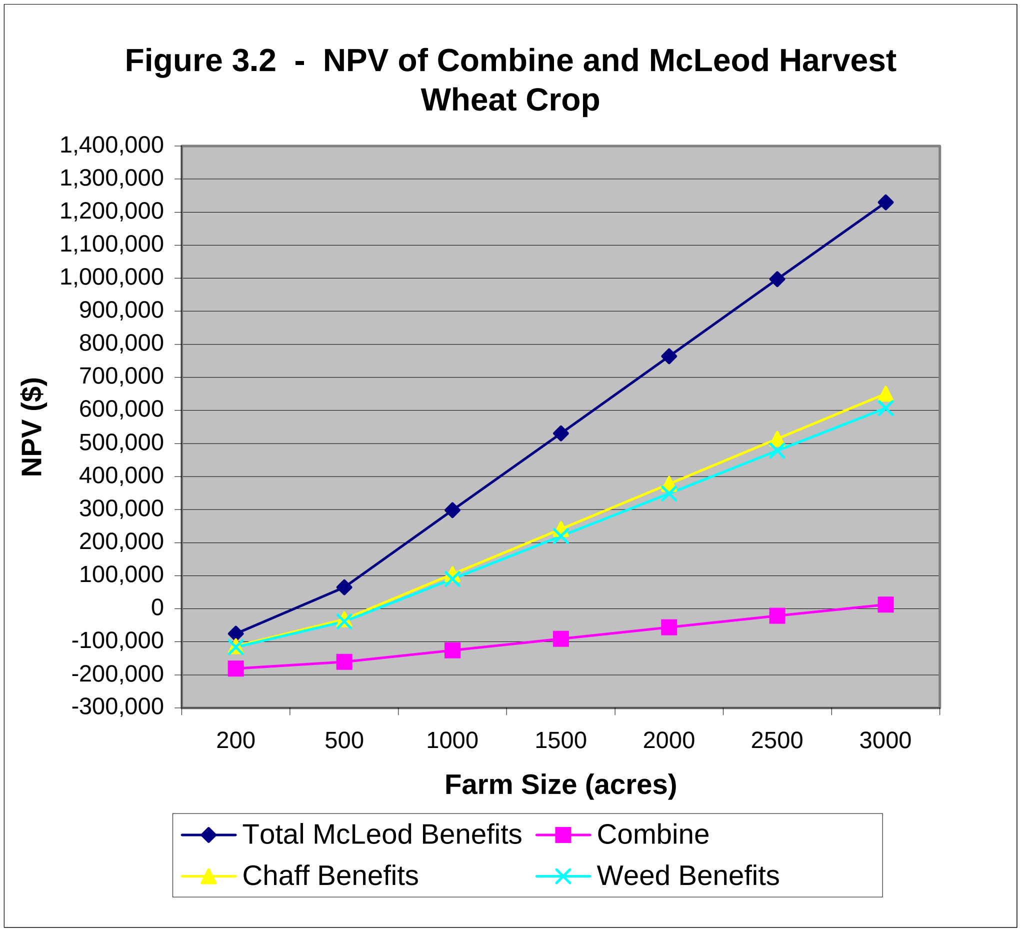
For the 1,000 acre farm, the IRR of the combine remains negative, while the McLeod Harvest earns a 30% rate of return. Only on the 2,000 acre farm does a combine have a non-negative IRR of 0.4%. The McLeod Harvest IRR grows to 88% for the 2,000 acre farm. The NPV remains negative for the combine in both the 1,000 and 2,000 acre cases, at ($125,625) and ($56,226) respectively.

Figures 3.1 and 3.2 illustrate the IRR and NPV of the combine and McLeod Harvest system across different farm sizes. The individual benefits of improved weed management and the use of chaff as feed are also examined. Each of these singular benefits is compared to the total benefits of the combine to analyze different scenarios generated by McLeod Harvest operations.

For example, relatively clean fields with low weed populations may reduce the benefits associated with improved weed management of the McLeod Harvest. Similarly, some producers may choose not to incorporate livestock into their farming operations. They could then burn the chaff or sell it to another producer or feed lot, incurring the additional transportation costs to bring the product to market. The full benefits of improved weed management and using chaff as feed would not be realized in these cases.

Figure 3.1 - IRR of Combine and McLeod Harvest Wheat Crop





The financially superiority of the McLeod Harvest is impressive. A combine must be utilized on over 2,500 acres before it reaches financial viability. In contrast, the McLeod Harvest can reach an equal return at less than 500 acres. Even if a farmer captured only the benefit of improved weed management or the use of chaff as feed, the profitability of the McLeod Harvest still exceeds that of the combine.

3.4 EXTERNALITIES AND PUBLIC BENEFITS

In performing this benefit-cost analysis, positive and negative externalities are excluded from the quantification of cash inflows and outflows. Externalities are important however, and may play a role in the acceptance of the investment. The quantification of social benefits is beyond the scope of this report, but they are identified in this section.

The McLeod Harvest should be environmentally responsible as well as economically beneficial. The combine harvester and McLeod Harvest create different social benefits and costs in their operations. These externalities are depicted in Table 3.6.

Table 3.6 – Environmental Perspective

	Combine	McLeod Harvest
Fuel Consumption	Diesel, with 260 total hp requirement	Diesel – 170 hp field unit Electricity – 60 hp mill
Weed Control	Perennial and pre-emergent herbicide sprays and application	Physical collection of weed seeds, only perennial herbicide spray and application
Feed Byproducts	None	Energy equivalent to produce 525 lbs. of tame hay per acre
Trucking	Hauls only grain	Hauls graff, truck consumes slightly more fuel because of added weight
Soil Impact	Chaff windrows hinder seed and fertilizer placement that may cause poor stand establishment	Chaff is collected, removal has no effect on soil nutrients and contributes less to soil erosion than straw

Fuel Consumption

The McLeod Harvest system is more environmentally responsible because electric power is substituted for diesel engines. Fossil fuels such as petroleum are nonrenewable resources that produce greenhouse gases. Replacement with renewable resources such as hydroelectricity is an improvement. The McLeod Harvest also has lower total energy requirements than the combine.

Weed Control

Farmers have become increasingly dependent on agricultural chemicals to control weeds and increase yields. Canadian sales of crop protection products at the manufacturer's level reached $1.4 billion in 1997, representing a 19% increase over 1996 sales[15]. Herbicides represented 81% or $1.1 billion in sales, an increase of 21% over 1996. If the McLeod Harvest was able to cut herbicide applications by one-half, this would save Canadian farmers over $500 million in input costs each year.

Any reduction in the need for herbicides reduces the use of resources in their manufacturing, transportation, and distribution. Some of these activities are greenhouse gas producing. In addition, farmers would burn less diesel fuel in tractors applying less herbicide to their fields.

[15] This data can be found at the Crop Protection Institute of Canada website at www.cropro.org.

The importance of weed management to crop production has grown as a result of several changes to the agricultural industry. The onslaught of herbicide resistance has changed the nature of weed control. Several green foxtail populations have become resistant to Group 1 and 3 herbicides, while chickweed and kochia have become insensitive to chlorsulfuron, a Group 2 herbicide. One of the more disturbing discoveries was made in 1998 in northwest Manitoba, where wild oats populations were found to be resistant to four herbicide groups[16]. More alarming, these super weeds are developing resistance to herbicides that have never been used in the field before.

Genetically modified (GM) crops have been developed as a solution to control the problem of herbicide resistance. A gene is bred into the crop plant to provide it with resistance to a specific herbicide. However, GM crops have become a problem in themselves. Volunteer GM crops are hard to distinguish from conventional volunteer crops, and certain control methods will not work on both. GM crops also lack universal acceptance. The European Union currently imposes a ban on imports of genetically modified crops.

The McLeod Harvest changes the focus of weed control by utilizing a mechanical method of weed collection. Removal of weed seeds as a part of normal field operations is a long-term solution of weed management that eliminates the need for developing GM crops any further. The McLeod Harvest is in line with the goals of integrated pest management, through the continued use of crop rotations and reducing the amount of chemicals used in crop production.

Chemical runoff into groundwater remains an important concern. In the summer of 1998, chemical residues were detected in southern Alberta rainfall. Traces of 2,4-D, dicamba, and bromoxynil were detected in eight test sights in the Lethbridge area[17]. Reducing herbicide application reduces the negative effects of chemicals.

Feed Byproducts

Kernan (1987), and Rutherford and Gimby (1991) have proven the value of chaff as a source of livestock feed. The McLeod Harvest reduces the energy required to grow other sources of feed by gathering a formerly discarded source of biomass. Resources are conserved and freed to be utilized in other production practices. The McLeod Harvest saves the energy equivalent of producing 525 lbs. of tame hay per acre[18].

Trucking

The McLeod Harvest hauls approximately three to four times the amount of material in the combine system. As analyzed in *Chapter 5 – Operational Research,* the 600 bushel capacity of most tandem axle trucks that farmers are now purchasing is adequate to handle this increased volume. However, it is likely that slightly more fuel is required to haul a load of graff. One foot of height can be added to the truck to facilitate transportation of this voluminous product. This

[16] Western Producer, *Super Wild Oats Gains Herbicide Resistance*, August 13, 1998.
[17] The Western Producer, *Farm Chemicals Showing Up in Rain Water*, February 18,1999.
[18] Chaff yield was determined in *Chapter 5 – Field Benefits*.

increases truck capacity by 100 bushels at a cost of approximately $2,000. This cost is included in the capital budget analysis.

Soil Impact

Chaff collection has been recognized as a very important part of field management. Craig (1988) states that chaff tends to accumulate in windrows, causing poor seed and fertilizer placement. In addition, the phytotoxicity and high demand for nitrogen by chaff decomposition can contribute to poor stand establishment and growth in subsequent crops. Weed seeds and volunteer grain in the chaff contribute to weed populations of the field. Collection of chaff can subsequently reduce herbicide costs as well as tillage operations.

The loss of erosion protection and nutrients that may be provided by chaff must be given consideration as a potential cost of chaff collection. Stumborg and Townley-Smith (1997) report that the removal of chaff from the field has virtually no effect on soil nutrients (chaff contributes very little to nitrogen return). According to Rennie (1986), the removal of chaff contributes less to soil erosion than does the removal of straw. In fact, chaff removal might have a positive effect on soil tilth because chaff patches contain a high quantity of silicates.

4. FIELD BENEFITS

The crop material collection characteristics of different types of harvesting systems are presented in Table 4.1. The McLeod Harvest is able to achieve the benefits in field operations of the binder-threshing machine, while matching the speed and labour efficiency of the combine harvester. The collection of graff, and not simply grain, generates additional field benefits for the McLeod Harvest that combines fail to capture.

Table 4.1 – Crop Material Collection Characteristics of Harvesting Machinery

	Straw	Chaff	Weed Seeds	Grain
Threshing Machine and Binder	Blown onto pile at the farmstead/ or in the field	Blown onto pile at the farmstead/ or in the field	Collected and burnt	Bagged and later stored in grain bins
Combine Harvester	Spread onto field	Spread onto field	Spread onto field	Stored in bins, bulk transport
McLeod Harvest	Spread onto field	Collected by mill and used as feed	Collected by mill and pulverized for use as feed	Stored in bins, bulk transport

Graff collection by the McLeod Harvest captures weed seeds that would normally be discarded by the combine. Physical collection of weed seeds reduces the spread of weed patches and herbicide use. Graff, when processed by the mill, provides a valuable source of feed for cattle. Grain loss is reduced by the McLeod Harvest through incorporating the cleaning apparatus into a separate mill. Cleaning shoe loss experienced by the combine is thus eliminated. The mill is able to clean grain to export quality standards. The value of cleaner grain is then returned to the farmer.

Quantification of economic benefits requires an estimation of the physical volume and an assignment of value to it. This report relies on expert opinion and secondary published sources of information to determine quantities and values.

4.1 VALUE OF CHAFF

Chaff is a byproduct of harvesting, but definitions on its composition vary. This report uses a broad definition of chaff, which consists of glumes, hulls, short pieces of straw, leaf material, small grain kernels, and weed seeds that pass through the combine. Therefore, chaff removal constitutes the removal of all material contained in the chaff.

Current methods of chaff collection are awkward and inefficient. The most popular method of chaff removal utilizes a wagon towed behind the combine. An attachment on the combine directs chaff into the wagon. When the wagon is full, the farmer trips a switch and the wagon dumps the chaff onto the field. Olefort (1991) reports that the labour costs of these chaff collection systems exceed fixed costs. Most Canadian wheat farmers simply burn chaff piles when employing this method.

Feeding an essentially wasted source of biomass presents an opportunity to lower feed costs. Considerable research has been conducted on the benefits of chaff as a source of feed for cattle[19]. A study conducted by Saskatchewan Agriculture concluded that chaff based beef cow winter maintenance ration saves $0.22 per day per cow over the next cheapest ration (tame hay). If the average number of cows per farm is 100, the savings realized feeding a chaff-based ration for 100 days would be $2,200 (Craig, 1988).

Two values are needed to quantify the value of McLeod Harvest graff: the millings value ($/tonne) and chaff yield (lbs./acre).

Millings Value

McLeod millings are an enriched source of chaff feed, containing protein from crushed weed seeds and small or broken kernels of grain. Screenings from winnowing the grain are densified by a rolling mill to increase digestibility and reduce the handling of chaff. Physically damaging the weed seeds also helps to ensure that they are not inadvertently carried back to the field in the manure.

[19] Research includes Kernan (1986), Kernan et. al. (1990), and Rutherford and Gimby (1991).

Wittenburg and Christenson[20] have independently tested the nutritive value of millings produced by the McLeod Harvest. The value of millings varies with crop sample composition. For example, a dry year producing small, shriveled kernels that enter the millings greatly increases its protein content. The protein content of the millings is approximately double that of chaff. Protein content of 6 - 8% in ordinary chaff represents maintenance rations, while Wittenburg's tests from 1996 show millings protein levels of 12 - 13% that are adequate for weight gaining rations. The variability of millings composition makes it difficult to determine its value.

Tame hay is used as a proxy for millings because it is a likely substitute. The tame hay prices and production of Alberta, Saskatchewan, and Manitoba are shown in Table 4.2.

Table 4.2 – Tame Hay Production and Prices of the Three Canadian Prairie Provinces

	Manitoba		Saskatchewan		Alberta	
	Million Tonnes	$/Tonne	Million Tonnes	$/Tonne	Million Tonnes	$/Tonne
1993	2.97	65	2.54	65	7.35	70
1994	2.99	50	4.26	56	9.16	67
1995	2.09	55	2.18	63	7.62	81
1996	2.90	55	3.75	90	8.60	95
1997	1.45	65	1.63	91	4.49	87

Sources: Manitoba Agriculture, Saskatchewan Agriculture and Food, and Alberta Agriculture, Food and Rural Development

An average weighted price for tame hay production from the three Canadian prairie provinces is $73/tonne. This value ranges between $50 to $95/tonne, depending on location and the demand and supply of hay. Where hay prices are higher, the yield of chaff is generally lower. Hence, the use of an average price and quantity of chaff is likely to be fairly representative.

Chaff Yield

Chaff is a very heterogeneous product. The volume of chaff collected varies with crop yields, weather conditions, moisture at harvest, and the type of combine used (rotary combines tend to produce more chaff than conventional). The variability and inconsistency of chaff yields make its economic value difficult to estimate.

The Prairie Agricultural Machinery Institute (PAMI) has evaluated chaff collection from combines under different field conditions. PAMI harvests the crop at a constant moisture level, which strengthens the reliability of their chaff yield results. A 5 year average wheat yield of 35 bu/acre is used[21]. Table 4.3 illustrates the latest data from PAMI on typical wheat chaff yields.

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[20] Dr. Karin Wittenburg, Department of Animal Science, University of Manitoba, and Dr. David Christenson, Department of Animal and Poultry Science, University of Saskatchewan.

[21] Canada Grains Industry, *Statistical Handbook 96*, Canada Grains Council, Winnipeg, 1996.

Table 4.3 – Chaff Characteristics of Wheat

	Grain Yield (bu/ac)	MOG/Grain Ratio	Chaff/MOG (%)	Chaff Yield (lbs/ac)
Wheat	30 to 60	.9 to 1.2	20 to 40	325 – 1725
Typical	35	1	25	525

Source: Harvesting Division, PAMI

The percent of chaff in the crop increases with falling moisture at harvest and more aggressive threshing. Entz[22] collaborates wheat chaff yields that range between 500 and 600 lbs./acre, but observes that some new varieties easily exceed 1,000 lbs./acre. This report uses an average wheat chaff yield of 525 lbs/ac.

Value of Millings

Wheat millings material has an economic value of:

$73/tonne * 1 tonne/2205 lbs. * 525lbs/acre = $17.38/acre

The savings associated with the use of chaff as feed would be lower if producers do not incorporate livestock into their farming operation. The costs of transporting millings to market would have to be included in the analysis to determine if the selling of this feed to another producer or feed mill would be profitable. Selling only the high quality, McLeod mill screenings product to off-farm locations may prove to be a more viable alternative.

4.2 REDUCED GRAIN LOSS

Combine harvesting losses occur at the header, in threshing, and in winnowing. Header loss occurs when the crop is gathered. Header losses are likely to be similar for the McLeod Harvest and the combine. Threshing loss is defined as the amount of grain loss due to the operation of the threshing cylinder. Winnowing loss comprises the amount of grain loss due to the operation of the walker and the shoe. The combination of threshing and winnowing loss is used as a measure of combine performance. Studies show that grain loss is exponentially proportional to the rate of flow of material through the combine (Mailander, et al. 1983).

The McLeod Harvest experiences less grain loss than is normally associated with the combine because there is no shoe loss. Grain loss associated with the cleaning shoe is collected at the stationary mill in the McLeod system. The stationary mill can be monitored for grain loss or damage by checking the quality of the millings produced. Settings can then be adjusted as needed.

[22] Dr. Martin Entz, Department of Plant Science, University of Manitoba.

Economic Estimation

PAMI has measured the grain loss associated with different combines. These equipment evaluations were conducted under easy and hard threshing conditions. The average grain loss as a percentage of the total grain passing through the combine is shown in Table 4.4.

Table 4.4 – Average Grain Loss from the Combine

Wheat	Walker	Shoe	Cylinder
Easy threshing	1.5%	1.5%	0.375%
Hard threshing	1.5%	0.75%	1.5%

Source: Prairie Agriculture Machinery Institute

Our estimation of grain loss from the McLeod Harvest is based on a study of the conceptual design of the field unit conducted by Kor Product Design Inc (1995). The field unit still incurs straw walker losses. Cylinder loss can be reduced by half, because at least one-half of the unthreshed grain is captured in the field unit tank. The field unit eliminates all grain loss associated with the cleaning shoe, because the shoe is removed. Therefore, grain savings equal the amount of shoe loss and half the cylinder loss experienced during combine operations.

This report uses easy threshing as a benchmark for determining grain loss. Hard threshing redistributes grain loss from the cleaning shoe to the threshing cylinder. Using a 5 year average wheat price of $4.30/bu and wheat yield of 35bu/acre[23], the value of lost grain is:

$$1.5\% + 0.375/2 = 1.685\% \text{ grain loss} * 35 \text{ bu/acre} * \$4.30/\text{bu} = \underline{\$2.54/\text{acre}}$$

The value of reduced grain loss is influenced by the price of grain, the yield of the crop, and the efficiency of threshing and separation.

4.3 VALUE OF CLEANER GRAIN

Plant material passing through the combine is divided into three main product streams: grain, chaff and straw. Inefficient winnowing leaves some foreign matter in the grain. This foreign matter is referred to as dockage. Typical components of dockage include weed seeds, volunteer grains, grain damaged during threshing, unthreshed grain, plant material other than seeds, and dust.

The combine produces grain that contains approximately 3% dockage. Recent technological innovations reduce the level of grain loss in the combine to approximately 1 to 2% dockage. However, the McLeod Harvest can clean grain down to levels of less than 1% dockage, or export quality standards. The stationary separate mill has a specialized cleaning system incorporated into its design. Set off to the side of the mill's layout, the cleaning system is not subject to the

[23] Canada Grains Industry, *Statistical Handbook 96*, Canada Grains Council, Winnipeg, 1996.

shock and vibrations of a combine, and produces an end product with minimum levels of dockage. In addition, aeration and drying are made more efficient by removing debris from the grain.

Economic Estimation

Cleaner grain increases crop value. Savings are realized through a decrease in the amount of dockage transported. Producers are charged freight on the gross amount of grain, and are paid on the net amount (gross minus dockage).

An average combine produces an end grain product of approximately 3% dockage. If the McLeod Harvest reduces dockage to only 1%, it then saves 1.8 tonnes on freight of a 90 tonne hopper car. An average freight rate of $35/tonne is used; actual freight costs depend on shipping location. Hence, the savings realized through shipping cleaner grain is:

$0.70/tonne * 1 tonne wheat/36.744 bu * 35 bu/acre = $0.67/acre

The grain cleaning charge at country elevators still applies even if the grain is already cleaned to export standards. Because of grain pooling, all deliveries still pass through the cleaner located at the terminal elevators. Many of the new high throughput elevators are installing cleaning systems.

During the course of this research, some grain companies conceded that they might be able to wave the cleaning fee. Through efficient coordination with the grain elevator, producers could save the $3.50/tonne cleaning charge for wheat. Savings through delivering cleaned grain would then include an additional $3.33/acre, bringing the total value of cleaner grain to $4.00/acre. For the purposes of this study however, only the savings in transportation cost are included in the benefit-cost analysis.

4.4 IMPROVED WEED MANAGEMENT

Weed management is an important and necessary part of crop production. Weeds have many negative effects on competing crops. Yields are lowered as weeds utilize inputs such as fertilizer and water that supplement the growth of the crop. Weed seeds can sometimes be difficult to separate from grain (e.g. mustard seed in canola), and crop value is subsequently reduced as weed seeds lower the grade that the grain receives. Dockage is also increased as a result of weed seed content.

The McLeod Harvest uses a mechanical method of weed control. Collecting all crop material except straw, the McLeod Harvest physically removes weed seeds from the field. Entz estimates that 1 pound of chaff can contain up to 900 weed seeds. Weed seed collection lowers weed populations, and reduces the need for tillage and herbicide applications.

The McLeod Harvest will not eliminate all weeds. Weed seeds that hit the cutter bar, shatter and fall to the ground would not be collected. Early maturing weeds, low weeds, and weeds that are spread by roots would also not be captured by the McLeod Harvest. Tillage, crop rotations and selective herbicide applications would still be required to manage these weed populations.

The McLeod Harvest mill separates weed seeds from the grain and crushes them using a rolling mill. The rolling mill is effective in dehulling larger weed seeds such as wild oats and green foxtail (the two most prominent Canadian prairie weeds)[24]. The crushing of weed seeds reduces their viability and their protein content increases the nutritional value of millings.

Economic Estimation

There are two ways to reduce reliance on herbicide use for weed control: remove weed seeds from the field and reduce the spread of weeds within the field. The McLeod Harvest physically collects chaff and weed seeds that would otherwise be spread back onto the field. Combine harvesters are powerful spreaders of weed seeds, transporting weed seeds between 40 and 150 meters (Shirtliffe, 1999).

Entz (1999) conducted a study on the influence of the McLeod Harvest on weed seed dynamics, and quantified the benefits associated with weed seed collection. His study concluded that savings in herbicide costs are two-fold. First, savings are achieved through a reduction in herbicide application through physically reducing weed seed banks. It is estimated that one grassy and one broadleaf herbicide application could be skipped every three years. At a cost of $20/acre for herbicide control in wheat (Manitoba Agriculture, 1999), annual herbicide savings of $6.66/acre are achieved.

The second benefit stems from reducing weed patch spread through chaff collection. Shirtliffe (1999) modeled the effects of weed seed collection on patch spread. While initial weed patches may be difficult to remove, auxiliary patches caused by weed seed spread are prevented from becoming established. Herbicide savings are achieved provided that a patch-based spray strategy is adopted. Precision agriculture is gaining popularity across the Canadian Prairies. The use of global positional system (GPS) technology is used to map weed patches. This data is then transferred to the spraying unit that patch sprays these weeds.

Typically, farmers have been reluctant to employ economic threshold spraying because of weed seed spread from unsprayed plants. However, the McLeod Harvest removes virtually all weed seeds present in the crop. Entz (1999) estimates that the range in cost savings for patch spraying grassy weeds alone is $5.43/acre for the first six years, and $13.40/acre thereafter.

Total savings in herbicide costs are gained through weed seed removal ($6.66/acre) and patch based weed control. Given patch containment benefits of $5.43 to $13.40/acre, annual herbicide savings are estimated at $12.09/acre (short-term) and $20.06/acre long term (Entz, 1999). Hence, this report uses average herbicide savings of up to <u>$16.00/acre</u>.

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[24] This information is found in Entz's research on the "Influence of the McLeod Harvest on Weed Seed Dynamics in Cereal and Oilseed Crops". Small seeds such as red root pigweed are less likely to receive damage from the rolling mill. Further research may be necessary to examine the treatment of small seeds.

Producers managing fields with low levels of weed populations may benefit less from the McLeod Harvest. They might already profit from reduced herbicide expenditures, and the benefits of the McLeod Harvest with respect to improved weed management would be lower. However, the benefits of patch containment would still apply.

4.5 SUMMARY OF FIELD BENEFITS

A summary of the different field benefits achieved by the McLeod Harvest is presented in Table 4.5. Values may vary due to the inconsistency of field conditions. Chaff composition, weed pressure, crop yield, weather, and crop and feed prices all have a significant influence on the savings achieved.

Table 4.5 – Field Benefits of the McLeod Harvest

Field Benefits	
Value of Chaff	$ 17.38/acre
Reduced Grain Loss	$ 2.54/acre
Cleaner Grain	$ 0.67/acre
Improved Weed Management	$ 16.00/acre
Total Field Benefits	**$ 36.59/acre**

These field benefits are derived from different crop production variables. Collected chaff has value when utilized as cattle feed. Removed chaff reduces poor stand establishment and seed and fertilizer placement problems associated with chaff windrows. Simpler, separate machinery cleans grain more efficiently and reduces grain loss. Lower dockage reduces freight charges through shipping cleaner grain. Weed management is improved through the mechanical removal of weed seeds.

The field benefits have identical per acre values regardless of the farm size chosen. Annual savings on a 1,000 acre farm would be over $36,000. As a comparison, Statistics Canada reports the average Canadian farm income for 1996 was $23,977. These savings show the potential of the field benefits of the McLeod Harvest.

5. OPERATIONAL RESEARCH

The objective of the operational research is to examine the coordination among the three system components specified in the benefit-cost analysis. Bottlenecks and optimal system capacity are also investigated as part of the operational research.

Given the short window to complete harvest, reaping and threshing operations should be kept running nonstop. A perfect match between the field unit and the truck occurs when the field unit is ready with a full load of graff at the same time as the truck is returning from the yard. This rarely occurs in the current harvesting system. Grain hauling trucks usually have to wait for the combine. For instance, Saskatchewan Agriculture documents that in-field waiting time for a truck hauling grain from one combine is 47.0, 44.5, and 42.5 minutes for field-yard distances of 0.5, 1.0, and 1.5 miles, respectively[25].

The economic analysis of the McLeod Harvest is based on the assumption that it is operationally feasible in terms of labour requirements, even though the amount of graff produced by the McLeod Harvest is approximately 3 to 4 times greater than the amount of grain produced by the combine. This increased amount of material requires extra handling, but not necessarily increased labour[26].

If trucking becomes a bottleneck and causes delays in the McLeod Harvest system, then truck hauling coordination would have to be re-examined. The use of two trucks or a larger capacity truck might be necessary to ensure no delays occur for the field unit.

Different scenarios are analyzed in this report to test the McLeod Harvest's operational feasibility under a variety of different crops and field conditions. *Scenario 1*, the baseline model, is used as a reference. It examines average graff densities and harvesting capacities equal to that of the combine to determine whether the McLeod Harvest can handle graff under normal field conditions. The lowest graff densities are analyzed in *Scenario 2* to determine whether this new technology can operate under conditions that produce above average amounts of crop material.

Due to the removal of the cleaning shoe from the field unit, one of the potential benefits of the McLeod Harvest is it could increase harvesting speed/capacity. A 20% increase in harvesting capacity is examined in *Scenario 3*. *Scenario 4* analyzes the worst case scenario of lowest graff densities combined with an increase in harvesting capacity.

- *Scenario 1* – Baseline model (average graff density and harvesting capacity)
- *Scenario 2* – Lowest graff densities, average harvesting capacity
- *Scenario 3* – Average graff density, 20% increase in harvesting capacity
- *Scenario 4* – Lowest graff density, 20% increase in harvesting capacity

The following methodology is employed in the development of the baseline model and previously defined scenarios. Grain yield data are based on average crop yields as determined by Manitoba Agriculture. Chaff yields are calculated by multiplying grain yield by the Material Other than Grain (MOG)/Grain ratio, and then by the Chaff/MOG percentage. The Prairie Agricultural Machinery Institute (PAMI) has developed these ratios through the evaluation of different combine harvesters. The total mass of graff is calculated by adding the mass of grain to that of chaff on a per acre basis. Graff mass is translated into graff volume through the use of graff density.

Graff volume per hour is based on the harvesting speed for each crop. A system capacity of 600 bushels is used throughout the McLeod Harvest system in this simulation. This system capacity

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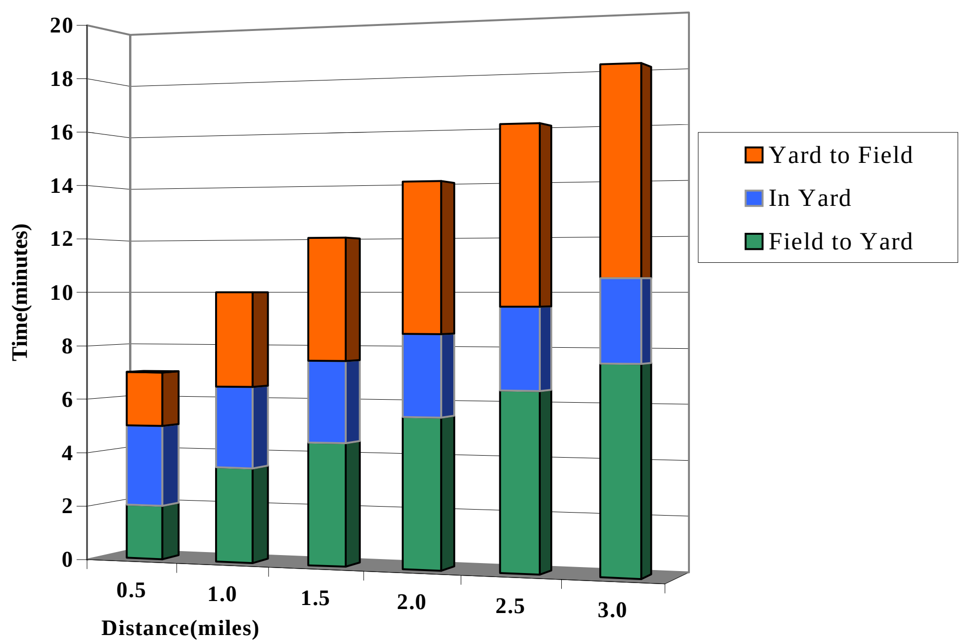
[25] Saskatchewan Agriculture and Food, *Farm Machinery - Custom and Rental Rate Guide 1998*, March 1998.
[26] The possibility that more labour will be required in the McLeod Harvest system still exists. However, the sizable savings of the McLeod Harvest system should justify any increased transportation and labour costs.

is found to be optimal in the simulation performed in *Section 5.1 - Optimal System Capacity*. From this capacity, the time to fill one load is calculated. The harvesting time of the field unit and off-the-field time of the truck are calculated and compared to determine the potential waiting time of each system component.

The travel time between the field and yard is modeled for various distances and is then used to construct off-the-field (OTF) time. The OTF time equals the sum of (1) the travelling time from the field to the yard, (2) the unloading time in the yard, and (3) the travelling time from the yard

Figure 5.1 - Off-the-Field(OTF) Time by Field-Yard Distance



back to the field[27]. The OTF times with respect to various distances are shown in Figure 5.1.

5.1 OPTIMAL SYSTEM CAPACITY

This section focuses on determining the optimal capacity of the McLeod Harvest system. If capacity is matched between system components, no manual handling of graff is required. Only the minimum capacity required by the field unit is calculated. Thus, the underlying assumption is that mill capacity could technically satisfy the demand from the other two system components. This approach, however, can by no means exclude the possibility that the mill is the system bottleneck. The concept of a two-phase cleaning process for the mill, which consists of a rough cleaning in harvesting season and a fine cleaning post-harvest, has been proposed to increase mill capacity if required.

[27] Truck loading time in the field, truck unloading time in the yard, and the relationship between distance and traveling times are estimated with reference to Saskatchewan Agriculture and Food, *Farm Machinery - Custom and Rental Rate Guide 1998*, March, 1998.

The optimal system capacity is examined for the following three crops: wheat, barley and canola. The simulation examines 3 system capacities: 400 bushels, 600 bushels and 800 bushels. Average graff densities and similar harvesting capacity to the combine are used in this evaluation. The crop specifications used to determine the optimal capacity are illustrated in Table 5.1

Table 5.1 – Crop Specifications

Crop	Wheat	Barley	Canola
Yield (bu/acre)	35	60	30
Chaff yield (lbs/acre)	525	460	1200
Graff/acre (tonne/acre)	1.19	1.51	1.22
Harvest speed (acre/hr)	10.00	10.00	9.00
Graff/hour (tonne/hr)	11.91	15.15	11.02
Density of graff (kg/m^3)	472.00	252.00	243.00
Volume/hour (m^3/hr)	25.23	60.12	45.36
Volume/hour (bushel/hr)	716.42	1707.37	1288.22

When 400 bushels is used as the system capacity, the following harvesting and truck waiting times are calculated for wheat, barley and canola. The results are presented in Table 5.2.

Table 5.2 – Harvesting and Waiting Time for a 400 bu Truck

	Wheat	Barley	Canola
Time to fill one tank(min)	33	14	19
Waiting time for haul of 0.5 miles	26	7	12
Waiting time for haul of 1.0 mile	23	4	9
Waiting time for haul of 1.5 miles	21	2	7
Waiting time for haul of 2.0 miles	19	0	5
Waiting time for haul of 2.5 miles	17	-2	3
Waiting time for haul of 3.0 miles	15	-4	1

The time required to fill the 400 bushel field unit tank is 33 minutes for wheat, 14 minutes for barley, and 19 minutes for canola. This tank size is suitable for all hauling distances of wheat and canola. A system capacity of 400 bushels is insufficient for harvesting barley. The maximum hauling distance without interruption of the field unit is 2.0 miles. The field unit waits for up to 4 minutes for a truck haul of 3.0 miles when harvesting barley. Hence, a McLeod Harvest system capacity of 400 bushels can be used for all distances under consideration for wheat and canola, but cannot be used for barley for hauling distances greater than 2.0 miles.

The following harvesting and waiting times are calculated in Table 5.3 when 600 bushels is used as the system capacity.

Table 5.3 – Harvesting and Waiting Time for a 600 bu Truck

	Wheat	Barley	Canola
Time to fill one tank(min)	50	21	28
Waiting time for haul of 0.5 miles	43	14	21
Waiting time for haul of 1.0 mile	40	11	18
Waiting time for haul of 1.5 miles	38	9	16
Waiting time for haul of 2.0 miles	36	7	14
Waiting time for haul of 2.5 miles	34	5	12
Waiting time for haul of 3.0 miles	32	3	10

The harvesting time required to fill the field unit's 600 bushel tank is 50 minutes for wheat, 21 minutes for barley, and 28 minutes for canola. Since the 400 bushel tank was sufficient to handle the hauling distances under consideration for wheat and canola, the 600 bushel tank is more than adequate to handle these crops under the same conditions. A 600 bushel tank is also adequate to haul barley graff for hauling distances of up to 3.0 miles.

The harvesting time and truck waiting times for a system capacity of 800 bushels are calculated in Table 5.4.

Table 5.4 – Harvesting and Waiting Time for a 800 bu Truck

	Wheat	Barley	Canola
Time to fill one tank(min)	67	28	37
Waiting time for haul of 0.5 miles	60	21	30
Waiting time for haul of 1.0 mile	57	18	27
Waiting time for haul of 1.5 miles	55	16	25
Waiting time for haul of 2.0 miles	53	14	23
Waiting time for haul of 2.5 miles	51	12	21
Waiting time for haul of 3.0 miles	49	10	19

The harvesting time required to fill an 800 bushel tank is 67 minutes for wheat, 28 minutes for barley, and 37 minutes for canola. A system capacity of 800 bushels is sufficient to handle all hauling distances of wheat, canola, and barley.

The simulation on system capacity indicates that the adequate tank size and truck box size should be 600 bushels. With a 600 bushel tank, no delays occur for the McLeod Harvest field unit. Lower graff densities and increased harvesting speed could possibly reduce the maximum hauling distances for each of these crops. These scenarios are examined in *Section 5.2 – Operational Feasibility*.

Barley is the only crop that comes close to causing delays in harvesting when utilizing a system capacity of 600 bushels. However, the optimal system capacity cannot be based on barley alone. Since barley tends to have the highest yield and among the most bulky graff, other crops generally require a smaller tank. If the optimal size were based solely on barley, over-capacity would always occur in harvesting other crops such as wheat and canola.

5.2 OPERATIONAL FEASIBILITY

Different scenarios, which have been previously explained at the beginning of this chapter, are analyzed in this section to determine the operational feasibility of the McLeod Harvest. These scenarios are designed to test the operations of the McLeod Harvest under a variety of different crops and conditions.

Scenario 1 provides a baseline model for comparison against the different conditions of the other scenarios. As shown in the results from *Scenario 1* in Table 5.5, the graff volume harvested per hour varies across a spectrum of different crops, due to the differences in crop yield, chaff yield, graff density, and harvesting speed.

Table 5.5 Scenario 1 - Baseline Model

Crop	**Wheat**	**Barley**	**Canola**
Yield (bu/acre)	35	60	30
Chaff yield (lbs/acre)	525	460	1200
Graff/acre (tonne/acre)	1.19	1.51	1.22
Harvest speed (acre/hr)	10.00	10.00	9.00
Graff/hour (tonne/hr)	11.91	15.15	11.02
Density of graff (kg/m^3)	472.00	252.00	243.00
Volume/hour (m^3/hr)	25.23	60.12	45.36
Volume/hour (bushel/hr)	716.42	1707.37	1288.22
Field efficiency (1 or 1.2)	1.00		
Truck capacity	600.00		
Time to fill one tank(min)	50	21	28
Waiting time for haul of 0.5 miles	43	14	21
Waiting time for haul of 1.0 mile	40	11	18
Waiting time for haul of 1.5 miles	38	9	16
Waiting time for haul of 2.0 miles	36	7	14
Waiting time for haul of 2.5 miles	34	5	12
Waiting time for haul of 3.0 miles	32	3	10

The harvesting time required to fill the 600 bushel tank of the field unit is 50 minutes for wheat, 21 minutes for barley, and 28 minutes for canola. The field unit's harvesting time exceeds the truck's cycle time in all cases for wheat, barley, and canola. Truck waiting time ranges from 43 to 32 minutes for 0.5 to 3.0 mile hauls of wheat, 21 to 3 minutes for 0.5 to 3.0 mile hauls of barley, and 28 to 10 minutes for 0.5 to 3.0 mile hauls of canola. These values are based on off-the-field times for various distances as presented in Figure 5.1

Scenario 2 has the same specifications as *Scenario 1*, except that the lowest graff densities of these crops are substituted for the average ones used in the baseline model. Results are shown in Table 5.6.

Table 5.6 Scenario 2 - Lowest Graff Densities

Crop	**Wheat**	**Barley**	**Canola**
Yield (bu/acre)	35	60	30
Chaff yield (lbs/acre)	525	460	1200
Graff/acre (tonne/acre)	1.19	1.51	1.22
Harvest speed (acre/hr)	10.00	10.00	9.00
Graff/hour (tonne/hr)	11.91	15.15	11.02
Density of graff (kg/m^3)	**384.00**	**202.00**	**177.00**
Volume/hour (m^3/hr)	31.01	75.00	62.27
Volume/hour (bushel/hr)	880.60	2129.99	1768.57
Field efficiency (1 or 1.2)	1.00		
Truck capacity	600.00		
Time to fill one tank(min)	41	17	20
Waiting time for haul of 0.5 miles	34	10	13
Waiting time for haul of 1.0 mile	31	7	10
Waiting time for haul of 1.5 miles	29	5	8
Waiting time for haul of 2.0 miles	27	3	6
Waiting time for haul of 2.5 miles	25	1	4
Waiting time for haul of 3.0 miles	23	-1	2

Due to the decrease in graff density, the graff volume harvested per hour increases. Hence, the harvesting time needed to fill the field unit's tank decreases. The harvesting time needed to fill the 600 bushel tank of the field unit is 41 minutes for wheat, 17 minutes for barley, and 20 minutes for canola. The field unit's harvesting time exceeds the truck's cycle time in all cases for wheat and canola. Truck waiting time ranges from 34 to 23 minutes for 0.5 to 3.0 mile hauls of wheat, and 13 to 2 minutes for 0.5 to 3.0 mile hauls of canola.

The truck becomes the bottleneck at distances greater than 2.5 miles for barley. The lower graff densities and high yielding characteristics of barley reduces system coordination. The truck waits for up to 10 minutes at a hauling distance of 0.5 miles, but the field unit has to wait for 1 minute at a hauling distance of 3.0 miles.

Scenario 3 has the same specifications as *Scenario 1*, except that a 20% increase in field unit harvesting capacity is incorporated into the analysis. This increase in harvesting capacity is uniform across the spectrum of all crops under analysis. The simulation results are shown in Table 5.7.

Table 5.7 Scenario 3 - 20% Increase in Capacity

Crop	**Wheat**	**Barley**	**Canola**
Yield (bu/acre)	35	60	30
Chaff yield (lbs/acre)	525	460	1200
Graff/acre (tonne/acre)	1.19	1.51	1.22
Harvest speed (acre/hr)	10.00	10.00	9.00
Graff/hour (tonne/hr)	14.29	18.18	13.23
Density of graff (kg/m^3)	472.00	252.00	243.00
Volume/hour (m^3/hr)	30.27	72.14	54.43
Volume/hour (bushel/hr)	859.71	2048.85	1545.86
Field efficiency (1 or 1.2)	**1.20**		
Truck capacity	600.00		
Time to fill one tank(min)	42	18	23
Waiting time for haul of 0.5 miles	35	11	16
Waiting time for haul of 1.0 mile	32	8	13
Waiting time for haul of 1.5 miles	30	6	11
Waiting time for haul of 2.0 miles	28	4	9
Waiting time for haul of 2.5 miles	26	2	7
Waiting time for haul of 3.0 miles	24	0	5

A comparison of the results of *Scenario 1*, the baseline model, to *Scenario 3* shows that a 20% increase in harvesting capacity reduces the harvesting time required to fill a 600 bushel tank by 14-18%. The harvesting time required to fill the field unit's 600 bushel tank is 42 minutes for wheat, 18 minutes for barley, and 23 minutes for canola. Once again, the field unit's harvesting time exceeds the truck's cycle time in all cases for wheat and canola. Truck waiting times range from 35 to 24 minutes for 0.5 to 3.0 mile hauls of wheat, and 16 to 5 minutes for 0.5 to 3.0 miles hauls of canola. The truck also remains the bottleneck for barley with an 11 to 0 minute wait for hauling distances of 0.5 to 3.0 miles.

Scenario 4 is the worst case scenario in that the lowest graff densities are combined with an increased harvesting capacity of 20%. The simulation results are shown in Table 5.8.

The combined effects of an increase in harvesting capacity and lowest graff densities can be demonstrated by comparing the results of *Scenario 1* to *Scenario 4*. The harvesting time required to fill the field unit's tank is reduced by 32-39%, to 34 minutes for wheat, 14 minutes for barley, and 17 minutes for canola. Given that OTF times range from 7 minutes for a 0.5 mile haul to 18 minutes for a 3.0 mile haul, the field unit remains the bottleneck in all cases for wheat.

Table 5.8 Scenario 4 -
Lowest Graff Densities and 20% Increase in Capacity

Crop	Wheat	Barley	Canola
Yield (bu/acre)	35	60	30
Chaff yield (lbs/acre)	525	460	1200
Graff/acre (tonne/acre)	1.19	1.51	1.22
Harvest speed (acre/hr)	10.00	10.00	9.00
Graff/hour (tonne/hr)	14.29	18.18	13.23
Density of graff (kg/m^3)	**384.00**	**202.00**	**177.00**
Volume/hour (m^3/hr)	37.21	90.00	74.73
Volume/hour (bushel/hr)	1056.73	2555.99	2122.29
Field efficiency (1 or 1.2)	**1.20**		
Truck capacity	600.00		
Time to fill one tank(min)	34	14	17
Waiting time for haul of 0.5 miles	27	7	10
Waiting time for haul of 1.0 mile	24	4	7
Waiting time for haul of 1.5 miles	22	2	5
Waiting time for haul of 2.0 miles	20	0	3
Waiting time for haul of 2.5 miles	18	-2	1
Waiting time for haul of 3.0 miles	16	-4	-1

The truck waits for 10 minutes at a hauling distance of 0.5 miles for the field unit to harvest a load of canola. However, the truck becomes the bottleneck for canola at distances greater than 2.5 miles. At a hauling distance of 3.0 miles, the field unit waits for 1.0 minute for the truck to return.

Since it only takes 14 minutes for the field unit to harvest barley under this worst case scenario, the truck becomes the bottleneck in operations for barley at distances greater than 2.0 miles. While the truck waits for up to 7 minutes at a hauling distance of 0.5 miles, the field unit has to wait for 4 minutes at a hauling distance of 3.0 miles.

Given average operating conditions, the McLeod Harvest is operationally feasible. It can harvest wheat, barley, and canola without interruption of field unit operations. However, when harvesting capacity is increased or graff density is lowered, the coordination of operations of the McLeod Harvest machinery is compromised for certain crops and hauling distances.

The field unit remains the bottleneck in harvesting wheat for all conditions and hauling distances under consideration. When harvesting canola, the truck becomes the bottleneck under the combined effects of increased harvesting capacity and lowered graff density. Under this worst case scenario, the McLeod field unit waits for 1 minute for a hauling distance of 3.0 miles for canola.

Barley is the crop most likely to cause delays in harvesting with the McLeod Harvest. For *Scenario 2*, the truck hauling limit is 2.5 miles. For the worst case *Scenario 4*, the hauling limit is 2.0 miles. These conditions require an increase in hauling capacity, whether it is the use of two trucks or a single, larger capacity truck.

Barley only becomes a problem under these scenarios of below average conditions. Chances are rare for the density of an entire 600 bushel load of graff to be extremely low. More evidence is required to further justify the proposed 20% harvesting capacity improvement of the McLeod Harvest over the combine harvester. As a result, these worst case scenarios are less likely to occur in reality to delay harvesting.

5.3 SUMMARY OF OPERATIONAL RESEARCH

This analysis of the operational feasibility of the McLeod Harvest concludes that a grain truck with a box capacity of 600 bushels is required for efficient coordination in the McLeod Harvest system. Optimal system capacity was based on three crops: wheat, barley and canola. System coordination is closest to being compromised in the harvesting of barley. However, capacity cannot be based on barley alone, as over-capacity would occur in the harvesting of other crops.

Modifications could be made to increase box capacity if a truck with capacity less than 600 bushels is employed. A foot of height could be added to increase hauling capacity by 100 bushels, at a cost of approximately $2,000.

The McLeod Harvest is found to be operationally feasible under normal operating conditions. Increasing harvesting capacity or lowering graff densities does compromise coordination of operations for certain crops and hauling distances. Barley is the only crop that becomes a concern when considering unfavorable situations. However, it is unlikely that the density of an entire load of graff would be extremely low. The proposed increase in harvesting capacity of the McLeod Harvest also needs to be determined by further research.

6. TOPICS FOR FURTHER RESEARCH

Acceptance of new technology will depend on the economics of the equipment, the operational efficiency of the machinery, and business development. This report has examined and compared the capital and operating costs of the McLeod Harvest to the combine. Benefits generated by field operations were quantified. These benefits included chaff's value as feed, reduced grain loss, the value of cleaner grain, and improved weed management.

Various industry professionals have conducted research on the operations of the McLeod Harvest. Dr. Karin Wittenburg, University of Manitoba, and Dr. David Christenson, University of Saskatchewan, have analyzed the nutritional composition and feed value of the millings product. Dr. Martin Entz, University of Manitoba, has investigated the influence of the McLeod Harvest on weed seed dynamics in cereal and oilseed crops. Researchers such as Wayne Craig, Jack Kernan, Ewen Coxworth, and Mark Stumborg have spent considerable time and effort on different segments of chaff collection. Research ranges from chaff collection costs, chaff as a biomass for ethanol production, the feed value of chaff, and the improvement of the nutritional value of chaff through ammoniation and other methods. McLeod Harvest Inc. has conducted research on the density values of graff from different crops and the development and testing of the McLeod Harvest method and equipment. The operational efficiency of the McLeod Harvest has been examined to determine optimal system capacity and possible bottlenecks in the graff handling system.

Using conservative estimates of benefits and costs, the McLeod Harvest system has an overwhelming economic advantage over the combine. As with any new system however, many secondary benefits may emerge because processes are done differently. Further research needs to be conducted to determine the true potential viability of this new harvesting system. Certain areas have been identified where further research would be beneficial.

6.1 ANIMAL SCIENCE RESEARCH

6.1.1 Livestock Nutrition

Ammoniation of chaff could enhance the millings value further. Ammoniation improves crude protein content, digestibility and greatly increases intake[28]. The scope of this report does not include an assessment of the benefits and costs of ammoniation of chaff. However, previous research conducted by Coxworth, et al. (1978) and Kernan (1987) shows that the potential exists.

6.1.2 Ethanol

A substantial amount of research and funding has gone into developing the potential of chaff in ethanol production. Coxworth, et al. (1981) identified cereal chaff as a promising source of biomass available for ethanol production. A preliminary assessment of the fermentation potential of chaff indicates that if all Saskatchewan cereal chaff were converted to ethanol, 830 million litres or 40% of Saskatchewan's gasoline production could be produced (Stumborg and Townley-Smith, 1997). Stumborg and Townley-Smith do not assess the benefits and costs associated with ethanol production from chaff; only the potential for ethanol production. Presumably, the residual feed material would still have some feed value.

6.2 PLANT SCIENCE RESEARCH

6.2.1 Volunteer Genetically Modified (GM) Crops

GM crops have been developed as an alternative to conventional herbicide treatment. They have also introduced a new type of herbicide resistant weed into fields – volunteer GM crops. Further research is required to determine the effect of the McLeod Harvest on future volunteer GM crop populations. It is difficult to quantify the savings that would be realized through the mechanical

[28]Kernan, J.A., *Investigation of the Ammoniation of an Uncovered Pile of Cereal Chaff*, 1987.

collection of volunteer GM crops, as these crops are relatively new. Research and development could be shifted to improving the agronomic traits of crops rather than developing herbicide resistant varieties.

6.2.2 Fusarium and Ergot

Fusarium headblight is a fungal disease that affects various grasses. This disease is characterized by premature bleaching of one or all spikelets in the head. Seeds in the spikelet stalk above the point of infection may not develop, reducing crop yields. Infected grain is shriveled and lighter in weight, and is often whitish in colour.

Preliminary testing from the 1998 harvest shows that the McLeod Harvest mill may have the ability to effectively remove fusarium from cereal grains. Airflow through the aspirator is increased to remove lighter, fusarium infected kernels. Screen size can also be selected to remove shriveled fusarium kernels. Infected kernels would be consequently crushed by the rolling mill, and dispersed throughout the millings pile. Finely crushed fusarium kernels should be spread evenly throughout such a large pile of millings and cause no ill effects when fed to cattle. The mill has the possibility to upgrade the crop in question and increase returns to producers. Future research is required to determine the full potential of the mill's ability to remove fusarium infected kernels from the grain.

Ergot is another fungal disease that affects many cereals and grasses. Yield reductions as a result of ergot are generally less than 10%. Ergot is easily identified by hard, black bodies that replace the grains of affected florets. The major problem with ergot is these bodies contain toxic alkaloids that are poisonous to humans and livestock[29]. Further research needs to be conducted to determine whether the screens of the McLeod Harvest mill could selected to remove these irregularly shaped ergot bodies.

6.2.3 Production of Organic and Non-Genetically Modified (GM) crops

The McLeod system favours the production of traditional crops that can be marketed on an identity preserved basis. Less use of herbicides through mechanical control increases the economics of organically grown grains. Consumers are willing to pay a premium for identity preserved grains (IPGs), and in some regions (e.g. Europe) resistance has grown to GM crops. The profit potential of using the McLeod Harvest to grow organically certified grains suggests that this target market deserves additional economic and logistics research.

6.3 BIOENGINEERING RESEARCH

6.3.1 Grain Loss

In this report, the lower levels of grain loss of the McLeod Harvest field unit are quantified and a value is assigned to these savings. The equipment prototype proves this concept. Further

[29] Manitoba Agriculture website, www.gov.mb.ca

research is needed to determine the true values of the three components of grain loss (walker, cylinder, and shoe loss), because the McLeod Harvest is fundamentally different than the combine. Research might also be directed at re-designing the threshing cylinder and the straw walkers to further reduce grain loss. The McLeod Harvest has more latitude to optimize these systems than the combine because grain winnowing is done separately.

6.3.2 Graff Storage

The storage properties of graff are largely unknown. It may be possible to store graff without protection, much as oats are stored, during the narrow window of harvest. This would facilitate the winnowing of grain from graff when farmers have more time. Graff storage would also promote the sharing of winnowing units and possibly the creation of larger processing plants that could clean and prepare grain for shipping. Research is recommended to determine the risk of loss or spoilage in graff piles.

6.3.3 Post Harvest Losses

Damage to grain during harvesting creates opportunities for insect infestation and fungus attack. The properties of the McLeod Harvest system have the potential to reduce cracking and damage to the seed coat that occur as a result of harvesting. The screening system of the McLeod Harvest utilizes increased air and larger cleaning screens to clean grain more gently, efficiently and with less physical damage than the combine. Research is needed to assess the status of the cleaning efficiency of the McLeod mill and suggest methods to further reduce damage that can be manifested in longer term storage.

6.4 FARM MANAGEMENT AND AGRICULTURAL ECONOMICS

By amalgamating harvesting functions into a single machine, the combine suffers from the pitfalls of congested operations. Harvesting functions are confined to the limits of the combine body and efficiency is lowered. The McLeod Harvest utilizes two pieces of farm equipment instead of one to perform the operations of harvesting.

Normally, some economies can be realized by joining functions, but there are also economic gains through specialization. Using specialized equipment for different harvesting operations allows for concentration on necessary functions. The McLeod field unit is concerned solely with the collection of graff. The absence of a cleaning apparatus in the field unit reduces grain loss and maximizes weed seed collection. The mill captures all grain and cleans it to a high standard. Specialization allows the use of larger screens and fans in the mill than would be possible given the confines of the combine body. Specialization achieves greater productive efficiency in the use of resources, which could have significant economic advantages beyond those already discussed.

6.4.1 Equipment Management

Joining harvesting functions into a single, combine harvester limits the opportunities for trading or selling machinery. The specialization of the McLeod Harvest machinery offers a higher degree of flexibility to farmers. More options exist in buying and selling machinery, as the upgrading of one piece of equipment can take place independent of the other.

Separate machines allow harvesting functions to take place at different times. This separation of operations facilitates the sharing of a portable mill between two smaller farming operations. Each operation would have its own field unit, and graff could be stored when the other owner was using the mill. Conversely, two producers may choose to share a field unit. This spreads equipment over more than one operation. These informal, machinery co-ops reap the benefits of shared labour, equipment and expertise. The economics of equipment co-ops deserve further attention.

Machinery part replacement can be difficult when working with large, intricate machinery. The confines of the combine body make accessing certain machinery operations difficult. The stationary design of the McLeod mill eliminates space constraints. The larger footprint of the winnowing mill makes replacement of parts an uncomplicated task.

Few options exist to reduce equipment costs substantially in the combine. Certain segments of the McLeod mill can be scaled down or removed altogether. The cleaning screen system and rolling mill could be removed, saving upwards of $25,000 of the mill's cost. Producers would be faced with dirty grain comprising weed seeds, dirt, stones, etc. (only the chaff would be removed). Grain could then be run through a smaller, more inexpensive screening system post-harvest, or cleaned inland at a primary elevator capable of export quality cleaning.

Productivity could be increased by making maximum use of existing equipment, including augers, headers, front-end loaders, etc. Using a tractor to power the field unit reduces duplication of farm equipment operations (utilizes the engine, transmission, and cab of the tractor). The McLeod Harvest could be made more economic by implementing different sized machinery according to farm size. Research is needed to identify the optimal size for various model scales.

6.4.2 Containerization of Grain

The McLeod Harvest mill cleans grain to export quality standards. Hence, grain could be shipped by other methods than the current bulk handling system. Grain could be conditioned on farm and loaded directly into containers dockage free.

Producers could earn additional revenue by serving niche markets. At current freight rates, container shipping is competitive with the total costs of bulk handling. Further research is required to determine the economics of storing and shipping export quality grain in containers.

7. SUMMARY CONCLUSIONS

An inherent tradeoff exists between crop residue management costs and the volume of material handled. The binder/thresher system captured the benefits associated with whole crop harvesting, but incurred significant labour and material handling costs.
The combine took a completely opposite approach to whole crop harvesting. Only grain is collected, while all chaff, weed seeds, and straw are returned to the field. The need to reduce labour costs outweighed the lost benefits of feeding chaff, and the increased use of herbicides for weed control.

The McLeod Harvest strikes a compromise between the material handling costs of the binder/thresher and the crop residue disposal of the combine. The McLeod Harvest collects all crop material except straw, which is left to improve soil tilth. Graff is transported to the stationary mill, where grain is cleaned and millings are used as a source of livestock feed.

The benefit-cost analysis demonstrates the greater profitability of an investment in the McLeod Harvest system versus the combine harvester. The internal rate of return (IRR) and net present value (NPV) are calculated for various farm sizes. The IRR and the NPV of the McLeod Harvest are greater than the combine for all farm sizes under consideration. Based on a 2,000 acre farm, the McLeod Harvest has an 88% IRR versus a 0.4% IRR for the combine. The McLeod Harvest also meets the NPV criteria for farms as small as 500 acres with an NPV of $25,229, while the combine does not reach a positive NPV until 3,000 acres.

The McLeod Harvest is able to achieve this level of investment potential because of lower capital and operating costs, reduced input costs, and additional revenue streams created by graff collection. These benefits associated with the McLeod Harvest are explained as follows.

Lower Equipment and Operating Costs

The purchase price of the combine has increased with larger equipment size and sophistication. The fundamental problem with the combine is that most farmers can no longer afford to purchase this equipment. Few businesses are structured with such a large amount of capital tied up in a piece of farm equipment that is used less than 30 days a year. While the economic life of a combine is about 15 to 20 years, the current replacement rate is much longer. Less expensive harvesting equipment deserves consideration as an alternative.

The capital cost of the McLeod Harvest equipment includes the field unit, mill, attributed use of a tractor, and truck box modifications if required. In total, capital costs of $192,000 for the McLeod Harvest are $24,000 or 11% less than the capital costs of $216,000 for the combine.

Operating costs are also lower with the McLeod Harvest in comparison to the combine. Hourly operating costs are estimated at $75.43/hr. for the combine and $60.65/hr. for the McLeod Harvest, representing savings of 20% or $14.78/hr. Savings are achieved in lower repair and maintenance costs as a result of longer lifetime of system components and lower capital costs. Fuel and lubricant savings are achieved through lower horsepower requirements and the use of electricity in the mill.

Collected Chaff has Value as Feed

Current methods of chaff collection are costly and inefficient. The chaff wagon, the most popular method of chaff removal, is towed behind the combine and tripped when full. These piles are later collected or burned. The McLeod Harvest integrates chaff collection into normal field unit operations. Chaff is collected along with grain in the McLeod Harvest and transported to the winnowing mill. The removal of chaff eliminates the problems of chaff windrows hindering stand establishment and seed and fertilizer placement.

The McLeod mill mixes chaff with crushed weed seeds, small kernels of grain, and other crop residue to form millings. The value of millings is considered to follow that of tame hay production and prices. This report estimates the value of wheat millings material to be $17.38/acre.

If the farming operation in question does not include livestock, then transportation costs of hauling the millings to another producer or feed lot must be considered. The value of millings to the producer would then have to be adjusted to reflect the marketing and transportation costs of selling the millings off-farm

Reduced Grain Loss

The McLeod Harvest experiences less grain loss than the combine because of the removal of the cleaning shoe from field operations. The cleaning apparatus of the combine is limited to the confines of the combine body, decreasing its efficiency in grain winnowing. The winnowing function of the McLeod Harvest is incorporated into the screening system of the mill. Grain loss associated with the cleaning shoe is thus captured in the millings. The mill can be subsequently monitored and adjusted to reduce grain loss. By eliminating cleaning shoe loss entirely and reducing cylinder loss by half, the McLeod Harvest saves $2.54/acre in grain loss.

Improved Weed Management through the Mechanical Collection of Weed Seeds

The McLeod Harvest captures weed seeds through its normal operations. All crop material except straw is collected by the McLeod field unit and transported by truck to the stationary mill. Hence, weed populations are controlled by physically removing weed seeds from the field. Tillage and herbicide operations are reduced as a result.

The McLeod Harvest can reduce reliance on herbicide use for weed control in two ways. The first is the physical removal of weed seeds from the field. It is estimated that one grassy and broadleaf herbicide application can be eliminated every three years. This represents a savings of $6.66/acre. The second benefit stems from reducing weed seed spread through chaff collection. A patch-based spray strategy is implemented because mechanically collected weed seeds are not spread by harvesting machinery. Patch containment benefits of $5.43 to $13.40/acre are achieved in the McLeod Harvest. In total, herbicide savings are estimated to be as high as $16.00/acre.

Herbicide savings will vary according to the weed populations found in the producer's fields. If a farmer already maintains low levels of weeds in the field, then the savings in improved weed management of the McLeod Harvest would be reduced.

Export Standard Cleaned Grain at the Farm Gate

Cleaner grain increases the crop's value. The McLeod Harvest is capable of cleaning grain to export quality standards. By comparison, the combine produces grain that has dockage levels from 1 to 3 percent. Producers are charged freight on gross weight, which includes transporting dockage. By eliminating dockage in shipments, the McLeod Harvest realizes $0.67/acre in savings through shipping cleaner grain. Potentially, these savings could be much higher because the cleaning tariff charged by the grain companies could be avoided.

Total Benefits

Total field benefits of the McLeod Harvest are estimated to be as high as $36.59/acre. Chaff composition, weed population, crop yield, weather, and crop prices all have a significant effect on the value of the field benefits.

The McLeod Harvest is significantly more economical than the combine. Annual total costs for a 1,000 acre farm are $32,348/year for the combine and $25,331/year for the McLeod Harvest, a savings of $7,017/year. Savings in total annual costs for a 2,000 acre farm are $9,234/year for the McLeod Harvest over the combine. Additional field benefits of $36/acre are generated by graff collection and improved efficiency of McLeod Harvest machinery. In total, the McLeod Harvest saves producers over $40,000/year for a 1,000 acre farm. For a 2,000 acre farm, savings generated by the McLeod Harvest over the combine are more than $80,000/year.

Operational Considerations

The operational efficiency of the McLeod Harvest is simulated in this report. The analysis concludes that a grain truck of 600 bushels is required for efficient coordination of the McLeod Harvest system. Optimal capacity was based on wheat, barley and canola. The McLeod Harvest was found to be operationally feasible under normal operating conditions. However, increasing harvesting capacity or lowering graff densities does compromise coordination of operations for certain crops and hauling distances.

Implications for the Future

The McLeod Harvest has a number of environmental benefits that deserve investigation. Greenhouse gas emissions are reduced through the substitution of electricity for diesel power in the McLeod mill. A formerly discarded biomass, namely chaff, can be used as a source of livestock feed. Herbicide application, production, resistance are all reduced through the mechanical collection of weed seeds.

Many opportunities exist to increase the profitability of grain farmers using the McLeod system. Further research is required to adequately assess the full potential of the McLeod Harvest method. Future topics include investigation into plant and animal science, bioengineering, and farm management and agricultural economics.

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APPENDIX A - McLEOD HARVEST INC.

Bob McLeod is the inventor and developer of the McLeod Harvest. With a farm, mechanical, and business background, he has owned and managed a number of businesses.

McLeod Harvest Inc. is a research and development organization totally dedicated to the development of the McLeod Harvest. The head office is located at 202 – 670 Broadway Ave. in Winnipeg, Manitoba. The method of research has been to retain the assistance of qualified individuals with industry experience and expertise and to devise tests and document results. A long-term test farm has been established at Hargrave, Manitoba. The company plans to complete research and development in 1999, and begin commercial introduction in the year 2000.

The McLeod Harvest has been under research and development since 1995, and field tested since 1997. Some research accomplishments to-date include 9 studies and reports, 5 patents (more applications are pending) and the design and testing of the prototype system. There has been demonstrated interest in the research by various professionals such as agricultural scientists, engineers, media, farm associations and farmers. The project has been nominated for 3 research prizes and awards. It has been the subject of 23 articles published in agricultural journals and newspapers, as well as 7 television and 10 radio stories. Over 600 farmers have formed a support group.

APPENDIX B - COSTS ESTIMATION

ANNUAL FIXED COSTS

The capital cost analysis follows the methodology developed by Iowa State University (Armes, Iowa) on "Estimating Farm Machinery Costs", PM 710 (Revised) September 1989[30]. Annual fixed costs are calculated as the sum of depreciation, interest, and insurance and housing costs. Calculations are influenced by the economic lifetime of equipment, salvage value, and the real interest rate applied.

Depreciation

Calculation of annual average depreciation is based on the following equation:

*Depreciation = Cash Price * factor * (1 – Salvage Ratio) / Economic Life;*

where the factor of annual activities and costs of the tractor attributed to harvesting is estimated at 20%, and unity for all other components.

Interest

The annual interest is calculated using the following equation:

Interest = Cash Price * factor * (1 + Salvage Ratio) / 2 * Real Interest Rate;

where the factor is equal to 20% for the tractor, and unity for all other components. The real interest rate, which is equal to the nominal interest rate minus the inflation rate, is assumed to be 5% throughout this study.

Insurance and Housing

*Insurance & Housing = Cash Price * factor * 1%;*

where the factor is equal to 20% for the tractor, and unity for all other components. A cost estimate of 1% of the cash price is used in determining insurance and housing costs.

Annual Fixed Costs

The annual fixed costs are calculated as the sum of depreciation, interest, and insurance & housing costs:

[30] This document can be obtained through the internet at www.ae.iastate.edu/pm710.htm

Annual Fixed Costs = Depreciation + Interest + Insurance & Housing.

Results

Annual fixed costs of the McLeod Harvest and the combine are summarized in Table B.1.

Table B.1 – Estimated Annual Fixed Costs of the McLeod Harvest and Combine

Estimated Fixed Costs	***McLeod Harvest***			***Combine***
	Tractor	***Field Unit***	***Mill***	
1. Salvage Value, % of retail price	$ 26,250 21%	$ 8,240 10.3%	$ 17,000 20%	$ 22,248 10.3%
2. Depreciation	$ 1,317	$ 4,784	$ 2,720	$ 12,917
3. Interest	$ 756	$ 2,206	$ 2,550	$ 5,956
4. Insurance and Housing	$ 250	$ 800	$ 850	$ 2,160
Total Fixed Costs	(2,323+7,790+6,120) **$ 16,233**			**$ 21,033**

The annual total fixed costs are $21,033 for the combine and $16,233 for the McLeod Harvest. Savings in fixed costs are 23%, or $4,800/yr. Over 10 years, the McLeod Harvest would generate savings of $48,000 in fixed costs alone.

Annual fixed cost savings are comprised of lower depreciation, interest, and insurance and housing costs. Savings in depreciation amount to $4,096/yr. The stationary nature of the mill and lower capital costs are the reasons for the lower level of depreciation experienced in the McLeod Harvest. Interest savings of $444/yr and insurance and housing savings of $260/yr are attributed to lower capital costs.

OPERATING COSTS

The operating cost analysis also follows the Iowa State University (1989) methodology. Hourly operating costs are based on repair and maintenance, fuel and lubricant, and labour costs.

Repair and Maintenance (R&M) Costs

Repair and maintenance costs are calculated as the lifetime hourly average for each component in the McLeod Harvest and the combine. The formula used is:

Hourly R&M Costs = Cash Price * RF /Lifetime Hours;

where RF is the repair factor; a percentage of the cash price that each piece of equipment will require in R&M.

Fuel and Lubricant (F&L) Costs

Hourly fuel costs depend on factors such as price of diesel, maximum PTO horsepower (MPTO), and average diesel consumption per hour (ADC). Lubricant costs are estimated as 10% of fuel
costs. The formula for F&L costs is:

Hourly F&L costs = MPTO * ADC * Diesel Price * 110%

where ADC is 0.16654 liter per hour and the price of diesel used in this study is $0.43/litre.

Labour Costs

Statistics Canada data indicates that the hourly wage rates for agricultural machinery operators in 1997 are:

- Manitoba - $9.71/hr.
- Saskatchewan - $9.50/hr.
- Alberta - $11.43/hr.

An average agricultural machinery operator wage rate for the Canadian Prairies is $10.21/hr. Taking into consideration the time required to lubricate and service machinery as well as time delays in getting to and leaving from the field, the actual hours of labour usually exceeds field machine time by 10 – 20%. As a result, wage rates are increased by an average of 15% to $11.75/hr.

Operating Costs

Operating costs per hour are the sum of repair and maintenance, fuel and lubricant, and hourly labour costs.

Hourly Operating Costs = R&M costs + F&L costs + Labour Costs

Results

Estimated hourly operating costs for both the McLeod Harvest and the combine are presented in Table B.2.

Table B.2 – Estimated Hourly Operating Costs of the McLeod Harvest and Combine

Estimated Operating Costs	*McLeod Harvest*			*Combine*
	Tractor	*Field Unit*	*Mill*	
6. Lifetime hours, % R&M of price	11,250 hr. 67%	2,250 hr. 45%	3,750 hr. 40%	2,250 hr. 45%
7. R&M per hour	$ 7.44/hr.	$ 16.00/hr.	$ 9.07/hr.	$ 43.20/hr.
8. F&L per hour	$ 13.39/hr.	-	$ 3.00/hr.	$ 20.48/hr.
9. Labour per hour	$ 11.75/hr.	-	-	$ 11.75/hr.
Total Operating Costs	(32.58+16.00+12.07)	**$ 60.65/hr.**		**$ 75.43/hr.**

Hourly operating costs are estimated at $75.43/hr. for the combine and $60.65/hr. for the McLeod Harvest. Operating savings of the McLeod Harvest are 20% or $14.78/hr. As it takes on average 150 hours to harvest 1,000 acres of land, hourly operating cost savings would be equal to $2,217/year. Over 10 years, the McLeod Harvest would generate savings of over $22,000 in operating costs.

Hourly operating cost savings can be attributed to lower repair and maintenance and lower fuel and lubricant costs. Repair and maintenance savings of $10.69/hr. are a result of longer lifetime of system components, lower R&M percentage of retail price, and lower capital costs. Fuel and lubricant savings of $4.09/hr are realized through lower horsepower requirements and the use of electricity in the mill. The Written-Pole motor, which operates on single-phase 220-volt electrical service, operates efficiently to reduce energy consumption in the McLeod Harvest mill.

TOTAL COSTS

Harvesting machinery is amongst the most expensive and least utilized pieces of equipment on the farm. The proportion of fixed costs to total costs associated with harvesting is therefore extremely high. Average total costs are very sensitive to annual utilization hours, which depend largely on farm size.

A trend has developed towards increasing farm size and correspondingly larger levels of operating revenue. Farmers seek to exploit economies of size by spreading the value of expensive farm machinery over a larger area of farmland. Total costs will be examined for two baseline models: a 1,000 acre and 2,000 acre farm.

The formulae used to develop annual total costs and total costs per acre are as follows:

*Annual TC = Annual Fixed Costs + Hourly Operating Costs * Annual Hours;*
TC per Acre = Annual Fixed Costs / Crop Acres +
Hourly Operating Costs / Hourly Harvesting Capacity.

Annual Total Costs

Table B.3 illustrates the total annual harvesting costs of the McLeod Harvest and the combine for a 1,000 acre and 2,000 acre farm.

Table B.3 – Total Annual Harvesting Costs and Savings for a 1,000 acre and 2,000 acre Farm

Annual Total Costs	***Fixed Costs***	***Operating Costs***	***Total Costs***
1,000 acre Farm			
Combine	$ 21,033	$ 11,315	$ 32,348
McLeod Harvest	$ 16,233	$ 9,098	$ 25,331
Savings	$ 4,800	$ 2,217	**$ 7,017**
2,000 acre Farm			
Combine	$ 21,033	$ 22,629	$ 43,662
McLeod Harvest	$ 16,233	$ 18,195	$ 34,428
Savings	$ 4,800	$ 4,434	**$ 9,234**

The annual total costs for a 1,000 acre farm are $32,348/year for the combine and $25,331/year for the McLeod Harvest. Therefore, the McLeod Harvest has a 22% cost advantage of $7,017/year over the combine. Savings in fixed costs amount to $4,800/year, while operating cost savings are equal to $2,217/year.

The annual total costs for the 2,000 acre farm are $43,662/year for the combine and $34,428/year for the McLeod Harvest. Although savings in fixed costs of $4,800/year are constant with respect to changes in farm size, the savings in operating costs for the 2,000 acre farm doubles to $4,434/year. Total savings for the McLeod Harvest are 21% or $9,234/year for the 2,000 acre farm.

Total Costs Per Acre

Total harvesting costs per acre for a 1,000 acre and 2,000 acre farm are illustrated in Table B.4

Table B.4 – Total Harvesting Costs per Acre for a 1,000 acre and 2,000 acre Farm

Total Costs per Acre	***Fixed Costs***	***Operating Costs***	***Total Costs***
1,000 acre Farm			
Combine	$ 21	$ 11	$ 32
McLeod Harvest	$ 16	$ 9	$ 25
Savings	$ 5	$ 2	**$ 7**
2,000 acre Farm			
Combine	$ 11	$ 11	$ 22
McLeod Harvest	$ 8	$ 9	$ 17
Savings	$ 3	$ 2	**$ 5**

Given the harvesting capacity and field efficiency of the two systems, the total costs per acre share a similar cost structure with respect to total hourly costs. Specifically, while the operating costs per acre are constant, fixed costs per acre decrease proportionally with an increase in farm size. The total harvesting costs for the 1,000 acre farm are $32/acre for the combine and $25/acre for the McLeod Harvest. The McLeod Harvest achieves savings of 22% or $7/acre over the combine.

Total harvesting costs for the 2,000 acre farm are $22/acre for the combine and $17/acre for the McLeod Harvest. Savings of 23% or $5/acre are obtained through the use of the McLeod Harvest over the combine.

APPENDIX C - IRR AND NPV CALCULATIONS

PRIVATE BENEFITS –VALUE OF GRAIN HARVESTING

These values were calculated with respect to the Guidelines for Estimating 1999 Crop Production Costs, Manitoba Agriculture, 1999. An explanation is given when deviating from specific production costs. A yield of 40 bu/acre is used, as 35bu/acre is unprofitable given these crop production costs.

		Wheat Value
Price	$4.30/bu	$172.00/acre
Yield	40bu/acre	

Wheat Expenses

Seed	$12.75/acre	
Fertilizer		*26.00*
Chemicals	23.50	
Crop Insurance	5.50	
Other Costs (2)	7.50	
Land Taxes	5.50	
Interest on Operating	4.07	
Land Investment	22.50	
Storage	2.32	
Fuel (3)	7.70	
Machinery Operating Cost (3)	7.00	
Machinery Depreciation (3)	12.60	
Machinery Investment (3)	6.30	
Labour (3)	***10.50***	
	$153.74/acre	

Value of Grain Harvesting $ 18/acre

Assumptions

(1) An average wheat price of $4.30/bu and yield of 40 bu/acre are used (Manitoba Agriculture).
(2) *Other Costs* include overhead expenses – hydro, phone, accounting, buildings, supplies and insurance, etc.
(3) Harvesting operations were given a weight of 30% of all crop production operations. Hence, *fuel, machinery operating cost, machinery depreciation, machinery investment and labour* are all represented as 70% of the Manitoba Agriculture figures.
(4) Operating and capital costs for the combine and the McLeod Harvest are assumed to be as presented in this document.
(5) The field benefits for the McLeod Harvest are assumed to be $36/acre.