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Research Update

739

Modeling and Comparing Whole Crop Harvesting Systems

In the early years of agriculture in the West, grain was cut, bound and hauled to a stationary threshing unit where the grain, chaff and straw were separated. Each product was used, either as a commodity or on the farm itself as feed or bedding for livestock. However as mixed farming became less common, chaff and straw became more of a nuisance to be disposed of or otherwise managed. Where straw management presented a particularly bad problem, stubble burning became a common management technique.

In recent years a great deal of research has been focused on developing systems to better manage straw and chaff in the field. The best alternative to burning is often proper straw spreading although even that option requires a lot of additional power and increased fuel consumption during combining. But as new markets begin to emerge for straw and chaff, such as ethanol production and strawboard manufacturing, innovative methods of whole-crop harvesting are being proposed.

The analysis in this report is based on industry standards and prior PAMI testing experience and data, including detailed testing of the whole crop baling method and test results from the stripper header harvesting method. Data for the McLeod harvesting system was provided by Bob McLeod of Winnipeg, Manitoba.

At a Glance

In general, it appears that the economics of the system improves as the amount of processing in the field is reduced.

The traditional windrow/combine system had the highest operating costs and the lowest Net Harvest Product Value (NHPV). In this system, the crop is cut and all of the processing takes place in the field. The whole crop baling system produced the highest NHPV of all the models tested. Here, the crop is cut and baled, then hauled to the yard where it is processed into grain, chaff and straw.

It is no coincidence that the windrow/combine system requires the highest amount of energy and the whole crop baling system the least. In-field harvesting systems must be powered by diesel engines and the entire system must be moved around the field as it performs its function.

In all systems, threshing the grain was a large part of the overall cost. On the other hand, by far the largest portion of the product value was derived from the grain. Swathing added a significant cost to the overall operation.

A large cost was associated with recovering the straw in all instances. In the whole crop baling system, rebaling the straw after processing—if necessary for shipment—would result in an additional $8,000 to the overall cost of the operation.

In the case of the stripper header model, the straw was obtained at a net loss because of the need for a separate swathing operation after the grain harvest. Also in this system, a large amount of the straw was lost when it was knocked down during the harvest operation. While collecting the straw from stripper harvesting appears to be uneconomical using current technology, the development of machinery and methods specifically for straw collection may produce more favourable returns.

Net returns for collecting chaff were also marginal. (This calculation does not include any agronomic benefits which may result from chaff removal). Systems where the grain and chaff were transported to the yard together for further processing had the best returns for chaff because of the lower transportation costs. However, development of new technology that considers chaff collection as an important component of the overall system may also improve the economics.

Project Description

In 1997, PAMI conducted an examination of harvest methods to assess their suitability for whole crop harvesting.

First, the project examined the performance of the relatively new harvest technique—the stripper header.

Secondly, five methods of harvesting—including the stripper header—were examined for their ability to efficiently collect and process grain, chaff and straw.

The total direct cost of each operation was calculated. However, indirect costs such as land, seeding and crop inputs were not considered. Energy consumption for each harvest method was also determined.

Revenues were estimated based on assumed prices and projected yields. Product yields varied slightly from system to system depending on factors specific to that system. For example, grain losses in the windrow/combine system were estimated at a standard 3%, while losses for the stripper header were set at 6% based on results from previous research. The different amounts of straw produced by the various systems were also considered.

Models were based on readily available, average size and efficiency farm equipment or projected costs and work rates for equipment not yet available.

A Net Harvest Product Value (NHPV) was determined for each system by subtracting the total operating costs from the value of the commodities produced. The NHPV provides a measure of the general efficiency of each system. The higher the NHPV, the more efficient the system is.

Net Harvest Product Value (NHPV)

Harvest System	NHPV
Windrow/combine	$87,700
Straight cut	94,600
Stripper header	94,900
McLeod	101,400
Whole bale (rebale)	103,900
Whole bale (no rebale)	112,000

Project Assumptions

For all the models in the study, a standard set of assumptions was used. These assumptions were based on industry standards or on the results of previous research.

Labour cost	$9.00/hr
Crop	Hard Red Spring Wheat
Crop height	36 inches (915 mm)
Yield	30 bu/acre (2 t/ha)
Field size	1000 acres (405 ha)
Grain value	$3.81/bu ($140/t)
Chaff value	$31.75/ton ($35/t)
Straw value	$31.75/ton ($35/t)
Hauling distance (field to yard)	5 miles (8 km)
Truck size (normal box)	350 bushels (wheat) (12.33 m^3)
Truck size (expanded box)	605 bushels (grain and chaff) (21.32 m^3)
Bale size	695 lb (315 kg)
Bales per load	8

t - metric tonne

The straw or crop was baled with a medium-sized round baler, hauled to the roadside, loaded on a semi-trailer and taken to the farmyard.

Trucking costs, fuel expenses, product weight, etc. held constant for all systems.

Practical Considerations

While the models have revealed the general economic advantages of the various systems, there are several practical considerations to take into account.

Although the windrow/combine system has the lowest NHPV of the systems tested, it is the only system that is adaptable to almost all crops grown on the Prairies. In addition, all the machinery required for this system is readily available. The combine provides the quickest way to harvest the high value grain and get it into secure storage. This is a prime consideration because of the Prairie climate. Windrowing allows the producer to cope with uneven maturity in a crop.

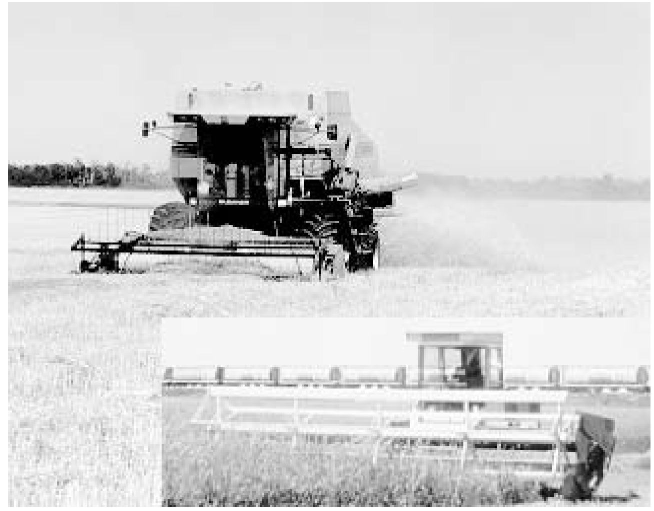
Straight cutting cannot be used for many crops, and the higher stubble left behind produces less straw and can result in higher straw losses in the tall stubble.

Specifically designed equipment to compliment the stripper header has not yet been developed. Currently, this type of header is being used on conventional combines. Though it does improve work rate, this is not the most efficient use of the combine because the stripper header produces mainly grain and chaff and the combine is designed to handle the entire mixture of grain, chaff and straw. The grain and chaff mixture may best be handled by a stationary processing unit which still needs to be developed, or by modifications to a basic combine to take advantage of lower straw quantities. In addition, the stripper header leaves the straw standing which requires an additional cutting operation, and in general, the stripper header only works well in cereal crops.

While a stationary processing unit for the McLeod system has been developed and is being improved, the development of a field unit is still in its early stages. It is not yet known which crops the McLeod system will be able to harvest most efficiently.

The whole crop baling system produced the highest NHPV. Once more, the main component of the system—a stationary in-yard processor—would still need to be developed. As with all other models except for the windrow/combine system, the whole crop baling system could not be used for crops where baling would result in a high grain/seed loss. This problem may be solvable with baler design modifications to ensure loose seeds are trapped in the bale.

Finally, some secondary benefits of chaff collection, such as the removal of weed seeds and potential disease reduction in future crops, were not measured or assigned a value.



The windrow/combine method is the dominant harvest system in western Canada today.

The Models

System One: Windrow/Combine

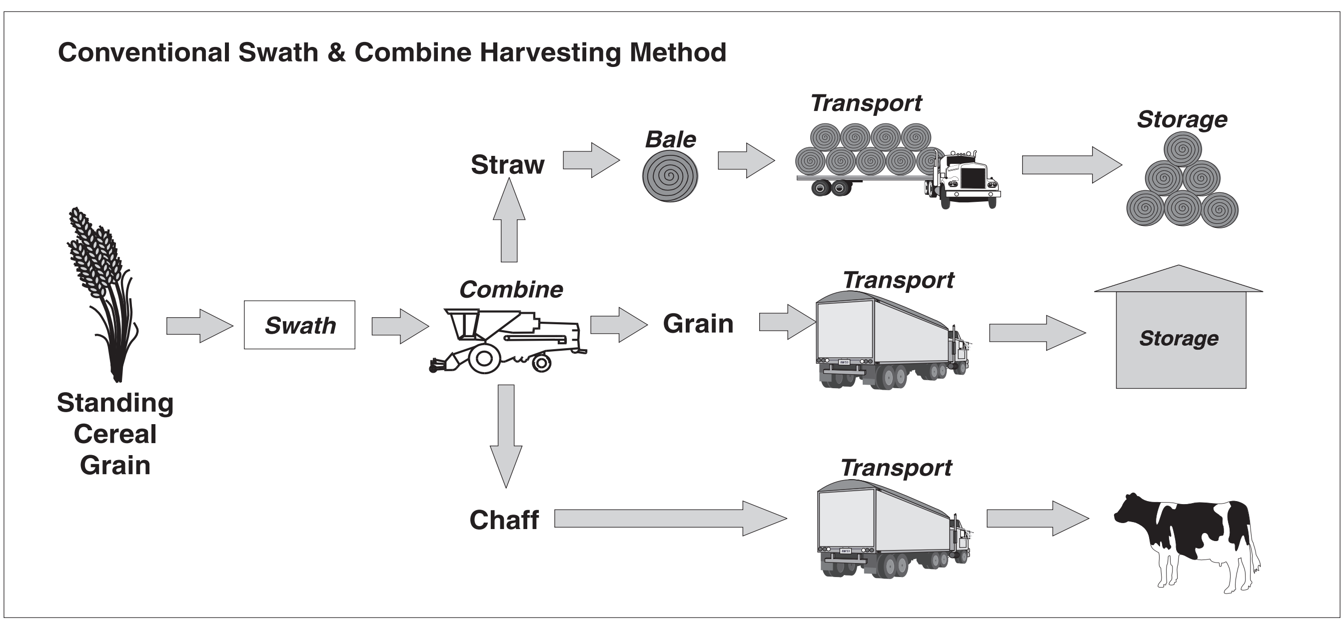
This is the dominant method of harvesting in western Canada today. The crop is windrowed (swathed), then harvested with a standard combine with a pick-up header. Straw and chaff is spread behind the combine or dropped in a windrow for baling later.

The major advantage of this system is that it can be adapted to almost any crop grown on the Prairies. In addition, the system provides the option of harvesting a little earlier by cutting the crop before it is entirely ripe, allowing it to cure in the swath if necessary. On the other hand, if rain occurs while the crop is in swath, it may take longer to dry than a standing crop.

Because the system involves separate cutting and threshing operations, it requires a high degree of management input. Because of the two operations and the additional power required to pass the entire crop through the combine, energy consumption is substantially higher than for other systems, and the combine work rate is slow because it is processing nearly all of the available plant material.

The Model

In this model, the crop was cut with a self-propelled swather at an eight-inch height and threshed with a standard combine with a pick-up header. Grain was hauled to the yard with a 350 bushel truck. Chaff was collected from the combine with a Redekop chaff collection system and hauled to the yard with a Redekop Chaff-O-Matic system. The straw was dropped behind the combine, baled with a round baler and moved to the yard.



The Results

The largest cost component in this model was combining (42%) because of the high capital cost of the machine, a relatively slow work rate and high energy consumption. Other significant costs included swathing the crop (14%) and baling the straw (22%). Hauling the products to the yard (grain, chaff and straw) accounted for an additional 20% of the total cost.

The windrow/combine system had the highest operating cost and the lowest NHPV of all the systems modelled. The system is not designed for efficient chaff collection, and indeed the chaff was collected at a net loss.

Windrow Combine - Cost/Revenue Summary*

Component	Cost of Operation	Product Value	Net Return
Grain	$26,000	$110,900	$84,900
Chaff	7,800	7,000	-800
Straw	15,700	19,300	3,600
	49,500	137,200	87,700

* Dollar figures have been rounded to the nearest $100 for ease of illustration.

System Two: Straight Cut

The straight cut system (see cover photo) requires one less field operation than the windrow/combine system resulting in less time in the field and lower energy consumption. With the growing use of pre-harvest desiccation to dry down the crop and remove green weeds, straight-cutting is becoming more practical in most of the Prairie region.

On the down side, straight-cutting cannot be used with many crops such as oil seeds and pulse crops. Also, the longer stubble resulting from the higher cut can reduce efficiency in chaff and straw recovery.

The Model

For this model, the crop was cut with a standard straight cut header at 12 inches. This height was chosen to increase the amount of material passing through the combine, allowing a closer comparison to picking up a windrow and increasing the amount of straw available for collection. Grain was hauled to the yard with a 350 bushel truck. Chaff was collected using a Redekop chaff collection system and hauled to the yard with a Redekop Chaff-O-Matic system. Straw was left in windrows behind the combine, baled and hauled to the yard.

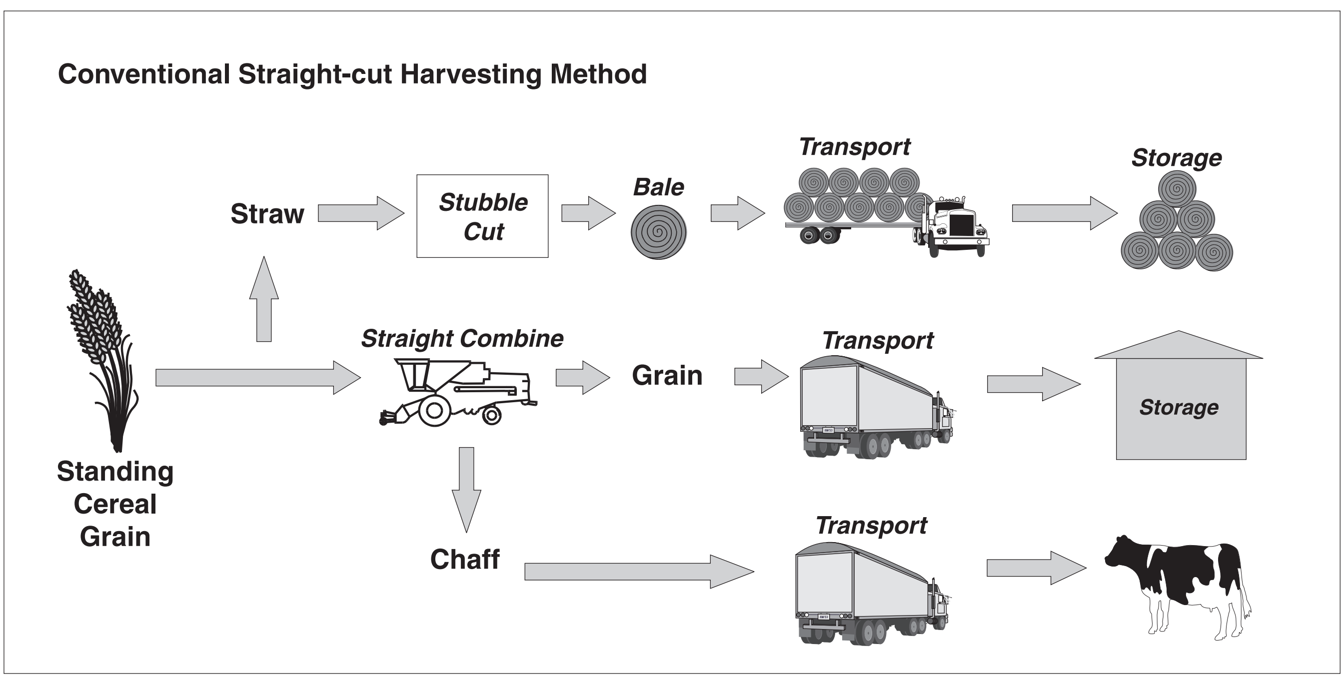
The Results

Although the combine work rate was faster than the windrow/combine system and energy consumption lower, the cost of running the combine was again the largest single expense at about 41% of the total cost. Baling the straw accounted for about 27% of the total.

However, overall costs were lower than the windrow/combine system because of the absence of the swathing operation.

Gross product values for chaff and straw were slightly lower for the straight cut system because of higher losses as a result of longer stubble and the reduced amount of straw available for baling because of the higher cut.

Overall energy consumption in this system was the lowest of all the systems tested except for that of the Whole Bale Cropping System.



Straight-cut System - Cost/Revenue Summary*

Component	Cost of Operation	Product Value	Net Return
Grain	$19,300	$110,900	$91,600
Chaff	7,300	6,900	-400
Straw	12,600	16,000	3,400
	39,200	133,800	94,600

* Dollar figures have been rounded to the nearest $100 for ease of illustration.

System Three: Stripper Header

Currently, stripper headers are being used on conventional combines in place of the straight cut or pick-up header. Most of the threshing is done by the header and as a result, much of the capacity of the combine itself is not used. A specifically designed harvesting machine would need to be developed to operate with the stripper header in order to fully capture its inherent advantages.

The stripper header is a very efficient method of collecting grain because of its low energy needs and the time required for harvesting. In effect, the stripper header removes the heads from the crop and leaves the straw standing. A separate operation is then required to cut the straw so other field operations such as seeding can be conducted with a minimum of problems. Also, some of the straw will be flattened in the harvesting operation, making it more difficult to recover later.

A limitation is that the stripper header may only be used efficiently with cereal grains.

Stripper Header Research

The stripper header has been under development for about 10 years. The working part of the header is a rotor of flexible teeth with a keyhole access between each pair of teeth. The rotor rotates in the direction opposite to that of a standard reel and as the crop heads pass through the recesses, the seeds and chaff are stripped from the plant. A conveyor and auger convey the grain and chaff into the combine.

The effectiveness of the stripper header was tested on canary seed and barley. For these tests, the stripper header was attached to a Massey Ferguson 550 combine.

Canary seed

In this test, less than 4% of the canary seed was threshed by the header itself. Previous studies found that as much as 86% of wheat was threshed by the header. One possible explanation for this difference is that the canary seed head is more likely to break off as a unit whereas wheat kernels are removed one seed at a time.

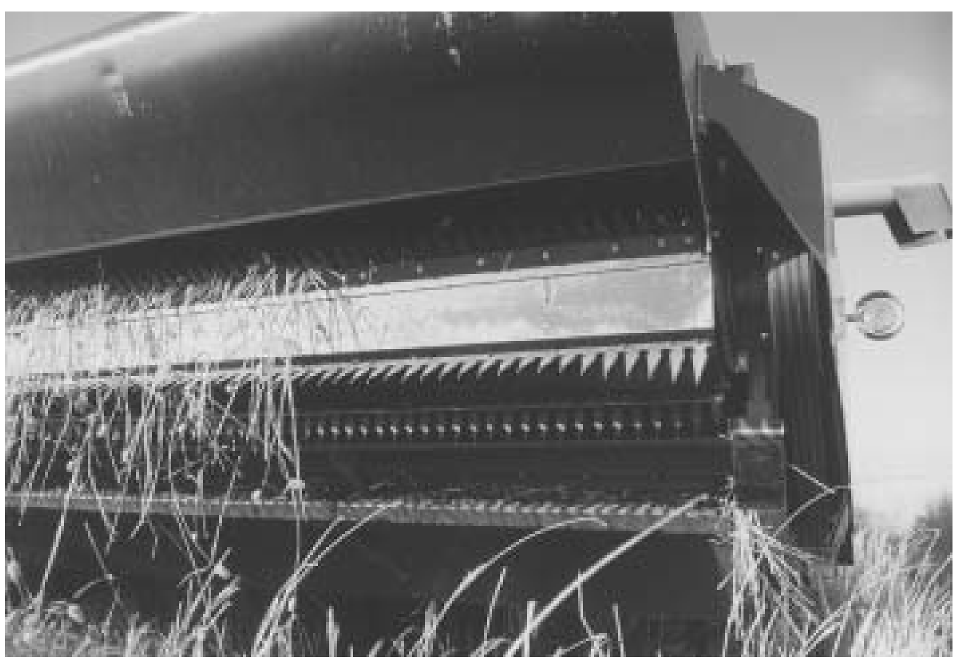
During the operation, many of the canary seed plants were also pulled from the ground intact. Individual canary seeds were also more likely to be lost from the header because of their very small size.

Barley

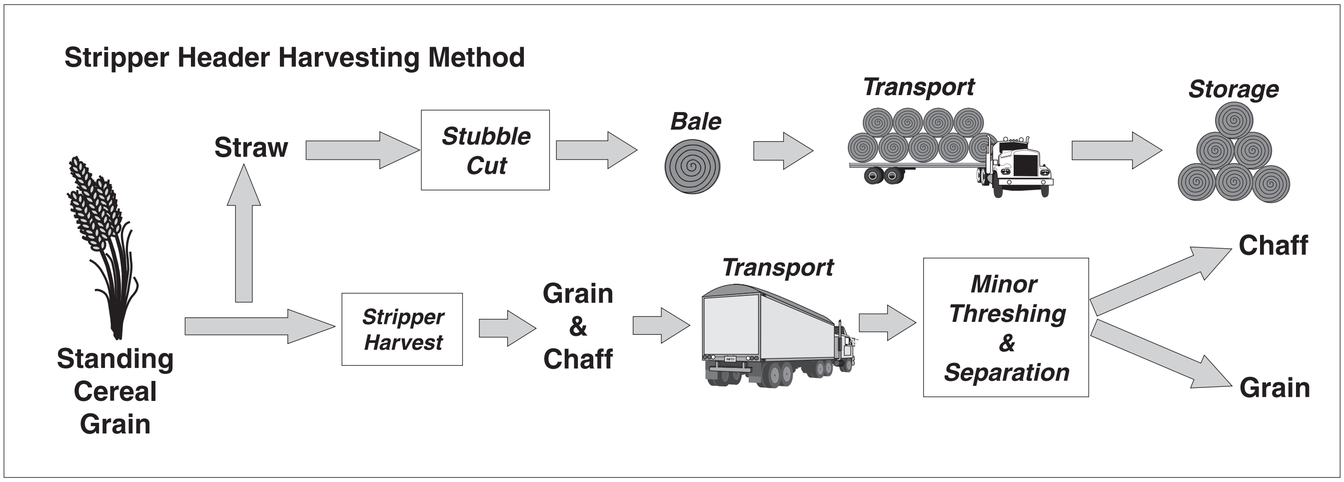
For barley, the majority of the threshing was done by the stripper header. Some secondary threshing occurred as the crop was handled by the table auger and beaters in the feeder house. In total, more than 92% of the barley was threshed before it reached the combine cylinder.

Conclusion

The stripper header, as part of an overall harvesting system, is suitable only for use with grains such as wheat, barley and oats, and similar types of plants. It operates best with well-anchored plants with a fairly large seed. With cereals, a very large portion of the threshing takes place during the stripping process. The stripper header does not work as effectively with small-seeded crops such as oil seeds and threshing does not take place in the header when entire seed pods are removed by the stripper fingers.



The stripper header does not work as effectively with small-seeded crops such as oil seeds and those where entire seed pods are removed by the stripper fingers.



The Model

The model assumed the stripper header was attached to a machine specifically developed for use with this header—a machine that could collect the chaff and grain from the header in a hopper without performing any further threshing or separating in the field. All of this material would then be hauled to the farmyard. Because of the bulkiness and the lighter weight of this mixture, the 350 bushel truck box could be expanded to hold the equivalent of about 600 bushels, making hauling more efficient.

The grain/chaff mixture would be rethreshed and separated in the yard by a processing machine.

Following the harvest operation, the standing straw in the field would be cut with a standard swather to an eight-inch height, baled and hauled to the yard.

The Results

The most significant costs in this system were cutting the standing straw (20%) after the stripper header had removed the heads, and baling (30%).

The cost of collecting the grain and chaff in the field and transporting it to the yard was relatively low compared to other systems. This was in part due to higher efficiencies in hauling the two products together in an expanded truck box. The cost of processing the grain and chaff in the yard was estimated to be only 7% of the total cost of the operation.

Grain losses with the stripper header are considered to be higher (approximately 6%) than with other systems, resulting in slightly less grain being collected.

If no treatment of the resulting stubble was necessary, harvesting costs would be very low. However, in reality, some method of managing the remaining stubble is necessary at this time. Future developments in seeding technology may make this unnecessary. In this model, the straw was collected at a net loss because of the need for a separate swathing operation.

Stripper Header - Cost/Revenue Summary*

Component	Cost of Operation	Product Value	Net Return
Grain	$12,200	$107,500	$95,300
Chaff	3,100	7,100	4,000
Straw	19,800	15,400	-4,400
	35,100	130,000	94,900

* Dollar figures have been rounded to the nearest $100 for ease of illustration.

System Four: The McLeod System

This system is being developed by Bob McLeod of Winnipeg. The proposed field unit, which is in development, would consist of a standard combine straight-cut header with a feeder housing and threshing cylinder. The grain and chaff are collected together in a large hopper and the straw passes over a set of straw walkers to collect any free grain. The unit would be pulled by a large two-wheel drive tractor.

The grain/chaff mixture would be transported to the farmyard where it would be processed further by an electric motor-driven unit already developed by McLeod.

The Model

For this study, it was assumed that the crop would be cut at a height of 12 inches, and the work rate would be similar to that of a straight-cut combine operation. The grain-chaff mixture would be hauled to the yard using the expanded truck box and processed further.

Straw discharged in the field would be baled and taken to the yard.

The Results

The total energy consumption of the McLeod system as modelled was quite high, second only to the windrow/combine system. This was largely because a tractor with enough power to pull and power the field unit would on average consume more fuel than a conventional combine. However, the energy consumed for harvesting and processing in total was still less than that for the windrow/combine system.

The operation produces about the same amount of straw in the field as does the straight-cut system because of the higher cut height.

The NHPV was the second highest of all the models tested. This was partly due to the efficiencies gained in transporting the wheat and chaff together and the relatively low energy consumption of the electric-powered processing unit.

The McLeod Harvesting System (Processor close-up, inset)

McLeod System - Cost/Revenue Summary*

Component	Cost of Operation	Product Value	Net Return
Grain	$16,500	$111,500	$95,000
Chaff	4,100	7,100	3,000
Straw	12,600	16,000	3,400
	33,200	134,600	101,400

* Dollar figures have been rounded to the nearest $100 for ease of illustration.

System Five: Whole Crop Baling

This model does not yet exist as an entire system. It has been based partly on existing machinery—swather and baler—and on assumptions based on previous research done to determine if crops could be baled and then threshed without loss of grain quality or quantity.

The Model

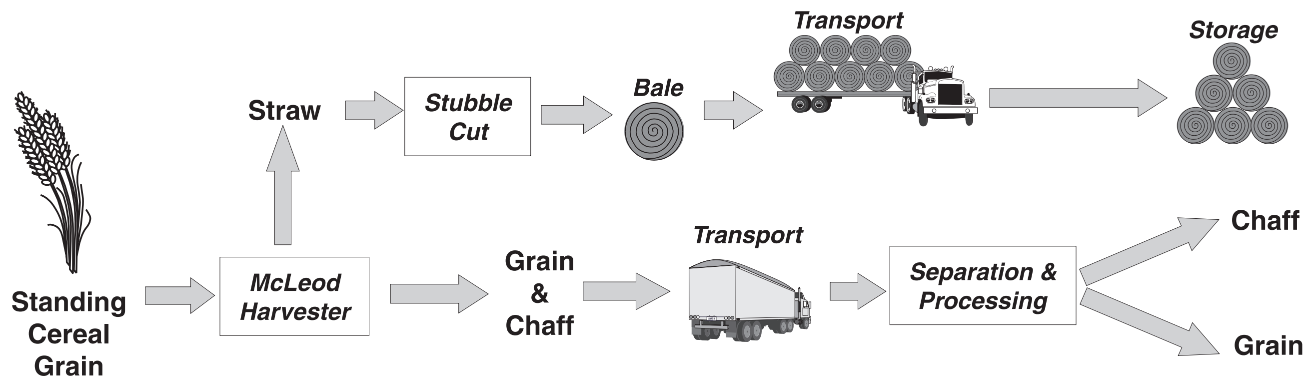
First, the crop would be swathed to a stubble height of eight inches. Then the entire unthreshed crop would be baled with a medium sized round baler and transported to the farmyard.

In the yard, the bales would be unwrapped and fed through a stationary processor that would perform all the functions of a normal combine. In order to compare the system fairly with others being examined, the assumption was made that the straw would be rebaled using a stationary standard round baler. Both the processing unit and the baler in the yard would be driven by electric motors.

The Results

The Whole Crop Baling system produced the highest NHPV even though the overall operating cost was slightly higher than the McLeod and the stripper header systems. This improvement in the NHPV may be attributed to the higher gross product values as a result of lower grain losses during the operation and significantly lower straw losses. Transporting all of the crop to the yard in one hauling operation added to the positive economics of this system.

McLeod Harvesting Method (Using Straight-Cut Header)



Whole Crop Baling -
Cost/Revenue Summary* - Straw Rebaled

Component	Cost of Operation	Product Value	Net Return
Grain	$13,800	$112,000	$98,200
Chaff	3,400	7,100	3,700
Straw	18,400	20,400	2,000
	35,600	139,500	103,900

* Dollar figures have been rounded to the nearest $100 for ease of illustration.

Whole Crop Baling -
Cost/Revenue Summary* - No Rebaling

Component	Cost of Operation	Product Value	Net Return
Grain	$13,800	$112,000	$98,200
Chaff	3,400	7,100	3,700
Straw	10,300	20,400	10,100
	27,500	139,500	112,000

* Dollar figures have been rounded to the nearest $100 for ease of illustration.

Rebaling the straw after threshing added a significant cost to the operation. If the straw had not been rebaled, the NHPV of this system would have been higher.

If a secondary use for the loose straw could be established at the processing site, costs could be reduced. As it is unlikely that an individual producer would be able to use all of the straw produced, this would only be feasible if the baled crop was hauled to a central processing facility where all of the products could be processed without rebaling the straw.

Need More Detail?

A detailed PAMI technical report (RH1196) on this topic is available. The 37 page report, entitled *Harvest Systems Model*, is available for a small charge.

Acknowledgements

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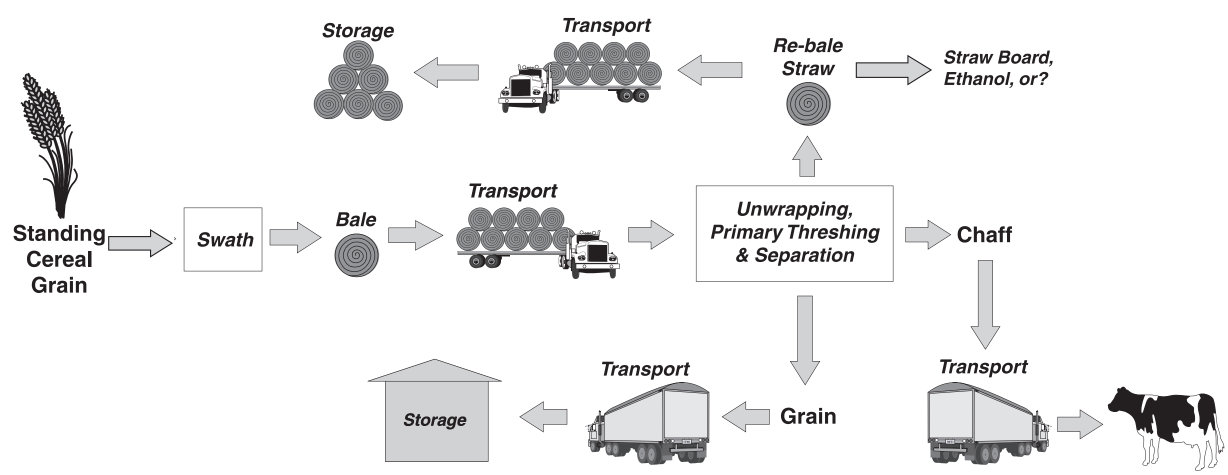
Whole Crop Baling Method



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