Single-pass baling productivity and grain logistics analysis

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Abstract
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Keywords
Single-Pass Baling, Corn Stover, Grain Logistics

Disciplines
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Comments
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Single-pass baling productivity and grain logistics analysis

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Abstract. Corn stover harvest in Iowa was studied using a single-pass combine and baler configuration over the last three years. The combine experienced a productivity loss from pulling a baler through the field of 6-10% depending on field conditions and speed. The additional biomass harvested by the combine lowered productivity depending upon the harvest rate and yield of the biomass. At the 1.4 ton rate in 2011 fall harvest the average maximum productivity loss was 25-30%. The loss was experienced in experiments without factoring in grain logistics. A model was developed to look at the field logistics of the grain cart to and from a single-pass combine when unloading on the go. The model showed that only a 16% loss in actual productivity when compared to a conventional combine which unloaded on the go as well.

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Introduction

Corn stover baling is progressing at an ever faster pace as two plants in Iowa start construction and will need to harvest 300,000 tons (6-700,000 bales) each by fall 2015. The large square baler has become the preferred unit of the Dupont Cellulosic Ethanol plant because of its ability to produce a dense and easy to handle bale that can withstand handling to the plant. Approximately 120 balers and tractors plus 170 shredders with power units and about 50-60 bale collectors will be required to service just one plant in a baling window lagging as much as 2 weeks behind the 27 days in which 80% of the corn crop is removed from the field in Iowa. A single-pass baler, beyond producing a higher quality bale would save at least 300 machine units from being purchased specifically for the corn stover harvest for each plant. A program would need to be developed in order to properly outfit and train producers to harvest corn and stover. A combine would either become the producer’s unit to harvest his grain or it would be a custom operation that would allow the plant to harvest the grain in return for the stover. A producer would have to be trained and compensated to operate a baler behind their combine. This compensation would be based upon material harvest rate, quality of the material, and productivity of the machine. Focusing on the productivity of the machine is key piece of this. If a baler is shared amongst multiple producers it will need to be operated continuously throughout the fall to have the most payback for the plant. It will also require more power from the combine to operate. This will limit the productivity of the machine in the field in operations that have near unlimited grain hauling capacity or in low yielding corn. In normal years in Iowa corn yields can be on average 173 bushels per acres (Iowa State University Ag Decision Maker, 2012), but in central Iowa a normal year can produce corn yields that are in excess of 200-250 bushels the logistics of keeping up with the combine in grain hauling can slow overall productivity down. This research looks at the effects that single-pass baling would have on combine productivity when the logistics of hauling grain affects the harvest progress.

When looking from a stand point of cost per ton research at Iowa State University by (Webster, 2011) shows that cost to harvest stover was reflective of two major areas. The first area was how much stover was harvested from the field on a ton per acre basis. The higher amounts of stover collected the less cost there was per ton. While the second factor was the reduction in productivity that the combine experienced as more stover was harvested. The cost seen in the previous research ranged from $25 per ton at .5 ton per acre with 15% reduction in productivity to $15 per ton at 2.5 tons per acre with a 45% reduction in productivity.
Methods

Field Test Setup and Equipment

In fall of 2011 1200 acres were harvested with an AGCO single-pass combine and baler near Jewell, Gilbert, and Ames, Iowa in Story and Hamilton Counties, United States. Along with the combine and baler a modified head was used to increase the take rate of corn stover. The equipment set for supporting the grain logistics was three 250 hp tractors, one 1000 bushel grain cart, and four 750 bushel gravity wagons hooked together into two sets of tandems. The wagons were chosen as the primary hauling method over a semi on the flexibility of using the wagons in many different configurations and projects within the research group. The diversity of grain hauling methods in central Iowa also makes it a feasible hauling method for many farmers since the on road capacities of paired wagons can exceed a fully legally loaded semi by 500 bushels. Grain was hauled to several local elevators and large capacity farm sites, all within 5 miles or less of a field site. This allowed for the tandem wagon sets to be hauled to the elevator with minimal effects due to differences in speed between a truck and tractor.
Bales produced by the combine and baler were dropped in the field and sat until a Stinger Ltd 6500 stacker came to pick up the bales and were hauled to the field edge. Two methods of testing were conducted during the fall. The primary tests conducted were productivity tests of the baler and combine in a variety of corn fields. This was to fully understand the effects of additional stover passing through the combine in a typical fall harvest. The tests conducted looked at harvest rates between .5 - 1.5 ton per acre and also looked at machine productivity with and without the baler. The tests consisted of 20 acre stover harvest strips and 10 acre non stover harvested strips. The second set of tests conducted was looking at the logistics of grain hauling from a combine and baler at a collection rate between 1-1.5 ton per acre and 150-200 bushels per acre corn.
For productivity testing, acreage was identified within each field and laid out in 10 and 20 acre blocks for each test. 10 acre blocks were used to test just the combine productivity while the 20 acre blocks were used to conduct productivity testing with the combine and baler in operation. Non collection tests were reduced in scope due to cooperator desire to have a field that was near uniform in harvest rate. In these tests the combine and baler would make complete passes through the field stopping to unload into an awaiting grain wagon as necessary. The combine was operated at a normal rate for a typical yielding field in Iowa.

A grain logistics model was developed in MATLAB based at Iowa State University to look at the effects of the cart on the combine’s overall throughput over the course of several cycles through a harvest. The input data for the model was built from data collected during the 2011 harvest of a conventional combine and the single-pass combine. The data was collected in productivity tests and from harvest of larger areas of corn harvested during the fall of 2011. The data from the model was analyzed using the Minitab statistical package.
Figure 4: The combine and baler unloading grain at the start of a productivity test pass in fall of 2011 harvest.

Figure 5: Combine with baler in tow, unloading on the go into a grain cart while conducting grain logistics tests.
Figure 6: A tractor and grain cart unloading grain along the edge of the field. The bale forks on the tractor allowed for bales to be easily moved from the path of the tractor or combine in the field and along the headlands without the need or presence of a stack wagon.

Figure 7: Not an uncommon sight in Iowa to see wagons in tow heading down the road to the elevator.
Results

Data from the productivity testing showed that in the 2011 fall harvest, the effects of the additional biomass passing through the combine were reduced compared to the testing done in 2010 harvest. At the 1.4 ton per acre average harvest rate, the combine’s productivity fell only 26%. The 26% reduction in harvest rate was an improvement over the previous research conducted at similar harvest rates. Part of the improvement was due to the threshing and cleaning capacity of the combine which allowed the increased amount of stover to be handled as there was more material being handled by the combine.

![Interval Plot of Grain Throughput (%)](image.png)

Figure 8: The total throughput of grain through the combine in a test. The conventional test at .5 ton per acre of stover was the normally set combine harvesting. As more stover and a baler were introduced to the combine the total throughput was reduced.

Comparing the productivity of the machine versus the output of the engine shows that in most tests the combine’s power was close to being fully utilized. When the combine was using a conventional header it was harvesting corn cleanly enough only to have about a .5 ton per acre of stover passing through the machine. At this level even with the baler the throughput and power of the combine was never limited. What was the limited factor in this was the ability of the header to take in grain. This backs up data from research conducted in 2010 from Webster et al (Webster, 2011).
Analysis of the grain logistics model shows that in a harvest system in which the conventional combine is operating in a conventional mode its top end ability to produce grain was limited to 4200 bushels per hour. In comparison the single-pass combine could output almost 3400 bushels per hour. That resulted in a 16% loss in productivity. That meant the actual combine productivity loss was reduced 10% versus the maximum productivity loss of the combine. In the model it was assumed that at the edge of the field there was an infinite amount of over the road transport for the grain. In order to achieve this level of capability two characteristics of the operation must be present. The first was the ability and capital of the operation to have machinery to haul the grain away. The requirement was to either have upwards of four semis and personnel to operate them or 2-3 sets of wagons and again personnel to operate them. The other characteristic needed would be to have a grain facility that would be capable of handling these high of a volume outputs from this combine and if the facility is an elevator have the capability of handling more than one producer.

![Interval Plot of Combine Engine % Load @ Speed](image)

Figure 9: This interval plot shows that through testing in which higher harvest rates were called for the engine of the combine was loaded at its highest showing a reduction in productivity. When the baler was hooked to the combine there was a higher trend in
The models show that the conventional combine will harvest more grain if there was an unlimited supply of vehicles for transporting the grain away. In the more likely scenario where the grain hauling was the limited factor the combines output would lower. Depending on how much the grain hauling system lowered the combine’s output the potential for it to be closer in output to the single-pass combine would mean that the conventional was stopped in the field waiting for a truck. The single-pass combine even when it was going slower would keep harvesting and utilize a larger portion of time of being operational in the field. On top of the increased utilization it would also save trips across the field from the multi-pass baling equipment. This would equal a savings of 1-3 trips total.

Comparing the cost of the single-pass baling to a multi-pass system shows that at the current average harvest rates from 2011, 1.4 ton per acre for single-pass and 1.3 ton per acre for a shred and bale multi-pass solution the cost actually favors the single-pass solution. An estimated cost at $16 per ton is quite favorable to the single-pass baling along with the factors of improved quality by means and less ash.
Another positive to the single-pass baling though was the ability not to leave a concentrated row of biomass in the field for every round the windrower makes. In the picture shown, the clean dry harvest rate was at 1.75 tons per acre. The biomass which is not harvest by the combine first doesn’t enter the machine and will not slow the machine down, also it will not be windrowed by the machine as it is harvested leaving a good even blanket of corn stover in the field.

Figure 11: This cost comparison of a multi-pass baling system versus and single-pass system shows that the single-pass baler will cost less. Mostly this is due less cost from the baler since the single-pass system can collect cleaner, higher quality material while nearly 8-10% of the material collected by the multi-pass baler is dirt and other foreign material.
Figure 12: This picture shows the potential residue left after taking 1.75 clean dry tons from a field during harvest. Note the material on ground was not disturbed or windrowed. In a multi-pass scenario this material would end up in a windrow. Also note that the leaves left in the field were shed during the fall and would have higher content of ash in raked or shredded into windrows.

Conclusion
The AGCO combine was able to handle higher rates of collection while harvest corn that averaged 173 bushels per acre. At 1.5 tons per acre the combine lost about 30% of its total productivity with all other factors disregarded. The total productivity can be improved when factoring in other factors that could slow harvest such as grain logistics or downed corn. When the other factors are included the combine can operate slower and have better utilization of its power and of the machine itself without extra downtime waiting for grain hauling.

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