TECHNOLOGY BACKGROUND AND BEST PRACTICES: YIELD MAPPING IN HAY AND FORAGE.

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TECHNOLOGY OVERVIEW

Over the last decade, researchers and equipment companies have worked to develop yield and moisture sensors that allow on-the-go collection of hay and forage yields in a spatial manner. Work has been conducted on windrowers, forage harvesters, large square balers and round balers. However, commercial implementation has been limited to the forage harvester and square baler, and the square baler application does not yet allow yield to be predicted spatially. Adoption has been slowed by three main factors: cost of the systems, uncertainty of payback given generally low forage crop inputs, and challenges associated with accurately estimating hay and forage moisture, which is needed to accurately determine DM yield. Moreover as sensor cost decreases and input costs increase, Precision Agriculture applications will make more economic sense for our hay and forage crops.

Yield at cutting was estimated indirectly by measuring conditioning roll force, roll displacement and crop impact force on the swath-forming shields (Shinners et al., 2000 and 2003). Impact force was the most successful technology applied on the windrower. None of these concepts have been commercialized, but they are promising as the windrower covers a larger portion of the field than the harvester and therefore could produce a higher resolution yield map.

Forage yield has been measured by a variety of sensors on the forage harvester, notably feedroll displacement, impact force on curved chute in spout, and cutterhead torque (Martel and Savoie 1999; Kumhála et al. 2007; Shinners et al. 2003; Savoie et al. 2002). Commercial forage harvester systems utilize the feedroll displacement system (Figure 2).

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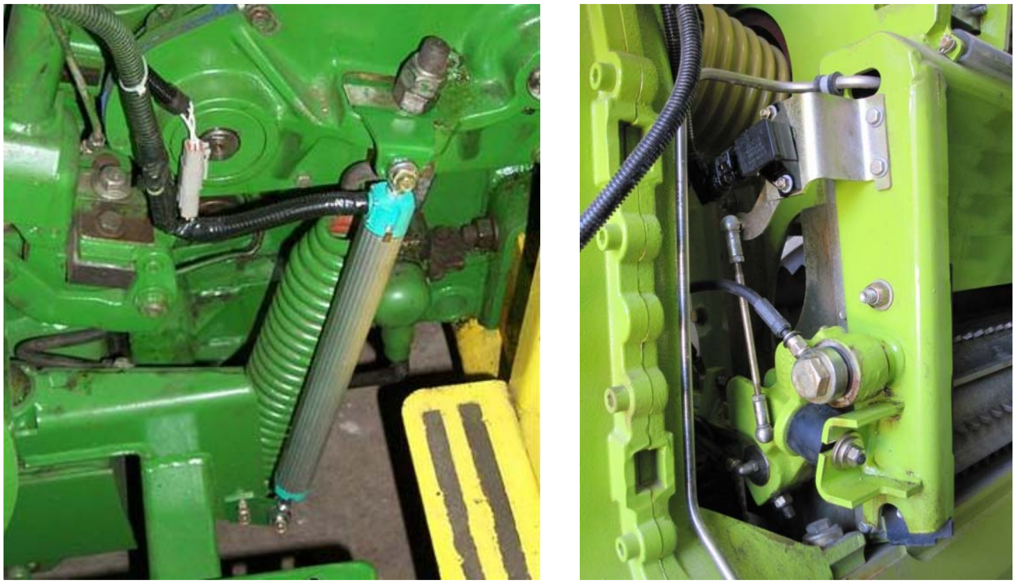

Figure 2. Linear (right) and angle (left) sensor for measuring feedroll movement.

Hay yield on the large square baler has been estimated by plunger force pulse width, bale displacement velocity through bale chamber, and weight of bale on the bale chute (Shinners et al., 2000). Directly weighing the bale on the chute was the most successful approach once individual bale weights could be systematically separated. To overcome this limitation commercial bale weighing systems utilize a segmented “tipping” bale chute. This mechanism isolates the current bale weight as it passes over the center of a pivot. The bale is then held briefly by a braking mechanism before being released to the ground (New Holland Agriculture, 2012). Although accurate bale weights are now attainable, these systems have not fully implemented other software and hardware necessary for yield mapping.

Figure 1. New Holland bale weighing system (photo courtesy of CNH Global N.V.)

Bale weighing on the round baler has yet to be commercialized, likely due to the cost of yield mapping technologies relative to the machine cost. However, weighing has been successfully accomplished by way of a load cell in the drawbar and axle spindles (Wild and Auernhammer, 1999). Initially dynamic effects of weighing while baling challenged the accuracy of this system. Throughout the course of their work Wild and Auernhammer did overcome this limitation with a system that combined bale diameter growth with a final weighing during wrapping and, as a result, could produce spatial measurement of hay yield with acceptable accuracy.

A key component of accurate yield mapping is crop moisture. To that end three different types of moisture sensor technologies are utilized on today's machines including capacitance, near infra-red reflectance (NIR) and microwave. Each technology comes with cost, capability and accuracy tradeoffs, which are reviewed briefly here.

Capacitance sensors come at a much lower cost but are calibrated at specific forage densities. Consequently, accuracy can suffer if the forage density is not close to that used in calibration. The capacitance sensor accuracy can be improved by entering a crop density correction factor. This process involves compressing harvested crop into a specific volume container and measuring the weight (density is the weight of crop per volume).

Figure 3. Capacitance, near infra-red reflectance and microwave moisture sensors.

Many people are very familiar with infra-red reflectance (NIR) technology as used in forage testing labs for measuring both moisture and constituents. Recent developments have brought this technology from the lab to the forage harvester (Digman and Shinners, 2008). The NIR technology is not only quite accurate, but recent developments are now allowing real-time measurement of common forage constituents (Deere & Company, 2012). NIR technology is quite expensive compared to other technologies, but there is real value to be achieved by real-time measurement of moisture and constituents.

Finally, the latest entrant to the hay market is microwave technology (Vomax, 2012). Microwave reflectance and transmission sensors have similar accuracy and costs to NIR but have significantly higher penetration depth when compared to NIR and therefore can more accurately represent the moisture content of the bale. However, this technology is limited to moisture measurement.

<u>BEST PRACTICES – FORAGE HARVESTER YIELD MONITOR CALIBRATION</u>

Since forage harvesters have the only commercialized yield monitoring system, our discussion of best practices is limited to these machines. However, one can envision the need for similar attention for round bale and large square bale systems that are on the horizon.

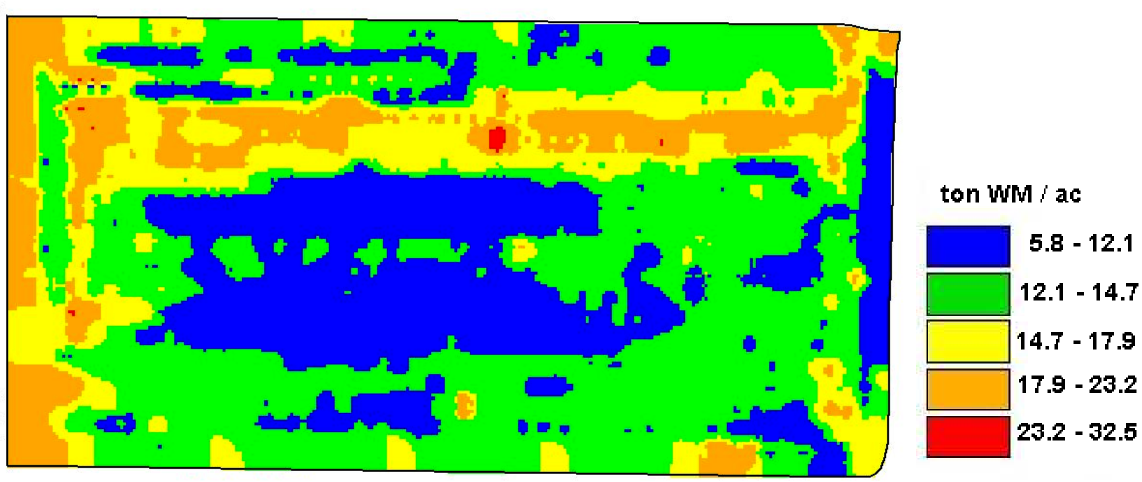

Figure 3. Whole-plant corn harvest yield map (Huenink and Shinners, 2003)

To build a yield map, the machine's electronics combine mass-flow (throughput), harvested width, speed and spatial location. Harvested width, speed and location are available from the machine's Global Navigation Satellite System (GNSS), commonly referred to as GPS here in the U.S. Calibration begins with ensuring the feedrolls start at the proper zero position. The feedroll position can move off the zero position when feedroll spring tension or mounting position is changed, or when crop builds up under the feedroll down stops. Consulting the operator's manual for specific points to check on the machine and for specific steps for the zero point calibration will ensure the most accurate reading. Also, some machines have a response threshold or minimum feedroll displacement, which will trigger throughput monitoring. This is much like the header height shut-off on combines. Corn silage may have a higher shut-off threshold than alfalfa or grass. It is necessary to check that a machine is set up for the crop it is intended to harvest.

Once the zero point and the response threshold are established, the system must be calibrated to match the volume (displacement) to the mass of the particular crop that will be harvested. Crop yield, moisture and species, as well as feedroll spring tension and length of cut, can have a significant effect on the yield prediction. Therefore, it is important to start the calibration process in a representative, uniform area of the field. Additionally, it is important to harvest at the speed of normal operation. This insures the calibration point is as close to the typical operating conditions as possible.

Generally, machines have a calibration “wizard” or step-by-step procedure to follow. As usual, it is important to make sure the container that is being loaded has a recent empty weight and that it is completely empty. Also, harvest a full load; however, in order to obtain an accurate calibration factor, do not overfill the container, as crop could be lost in transit to the scale. At this time, most machines allow the operator to resume harvest until the load weight can be entered into the calibration wizard. Once this weight is available, a calibration factor is calculated that relates the container weight to the calculated volume during the calibration run, based on feedroll displacement and time to fill the container. This factor now adjusts yield data recorded from this point forward. To accommodate varying field conditions, it is recommended that the calibration factor be adjusted at least once per day or when a noticeable change in harvesting conditions occurs.

As previously mentioned, moisture is a key component of accurate yield mapping. To insure accurate moisture prediction, it is important that the sensor has the latest calibrations from the manufacturer. It is also helpful to make sure the sensor’s lens is free of any scratches or excessive wear and is properly adjusted to interact with the harvester’s crop stream. The sensor lens needs to be periodically cleaned of material buildup, especially gummy material, to work properly. This often can be remedied by ensuring the sensor is properly adjusted to engage the crop stream or by cleaning with window cleaner and a rag.

With some attention to the details, it is possible to have a harvester that should be able to produce yield maps that will allow the same precision management expected in cereal crops. Forage yield maps, coupled with site-specific technologies in application of soil amendments, fertilizers, and pesticides will allow the crop manager to determine the resulting yield response for these management decisions. Yield improvement would not be the only factor increasing profitability as site-specific application of fertilizer and pesticides could lead to lower usage, resulting in lower input costs and environmental impact.

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