4. LESSON

YIELD SENSORS FOR FORAGES

Yield mapping of non-combinable plants

Non-smoothed flow, high mass yields and large range of the harvesting conditions cause serious problems during non-combinable products yield mapping.

Often mapped forages:

Maize (Corn-US)

Lucerne (Alfalfa-US)

Straw

Forage harvesters

The technology for throughput measurement, which could be used to determine harvested quantities and for yield mapping in forage harvesters is at lower stage of development although self-propelled forage harvesters are still some of the most expensive elements in agricultural machinery fleet.

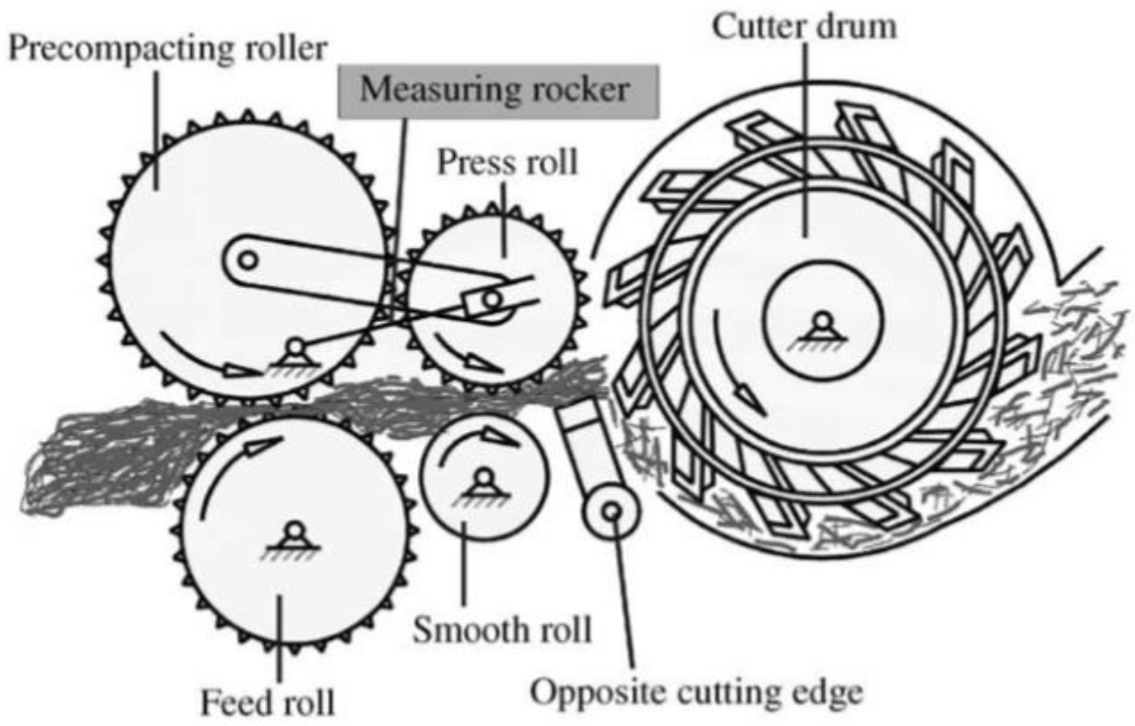
- Vansichen and De Baerdemaeker (1993) calculated yield from the torque of a forage harvester's blower.

- Measurement of the distance between feeder rolls of the harvester (Ehlert and Schmidt 1995; Auernhammer et al., 1996; Barnett and Shinners, 1998; Martel and Savoie, 1999; Schmittmann et al., 2001; Diekhans, 2002).

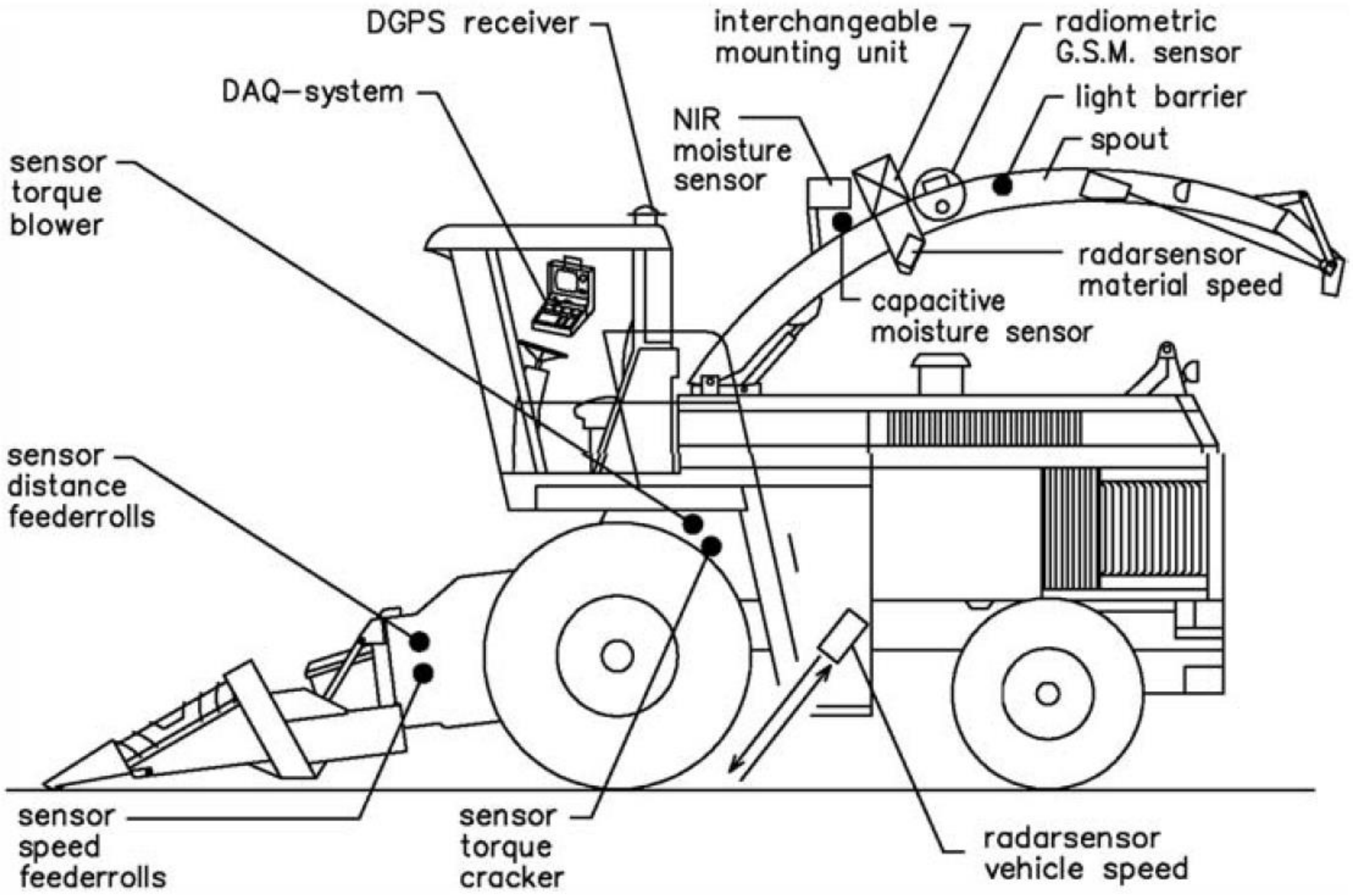
- A mass flow sensor for a pull type (trailed) forage harvester based on a reaction plate in the spout was constructed and tested by Missotten et al. (1997). Similar sensors were tested by other authors (Barnett and Shinners, 1998; Martel and Savoie, 1999, Schmittmann et al., 2001) for self propelled forage harvesters.

- Martel and Savoie (1999) measured electrical capacitance in the spout of a forage harvester.
- Schmittmann et al. (2001) measured crop layer thickness.

Some of these methods (e. g. distance between feeder rolls, reaction plate, and crop layer thickness) are applicable and showed a good coefficient of determination (R^2 = 0.94 to 0.98).
Some methods (e. g. distance between feeder rolls, electrical capacitance in the spout of a forage harvester) have to be supplied with several calibration parameters.

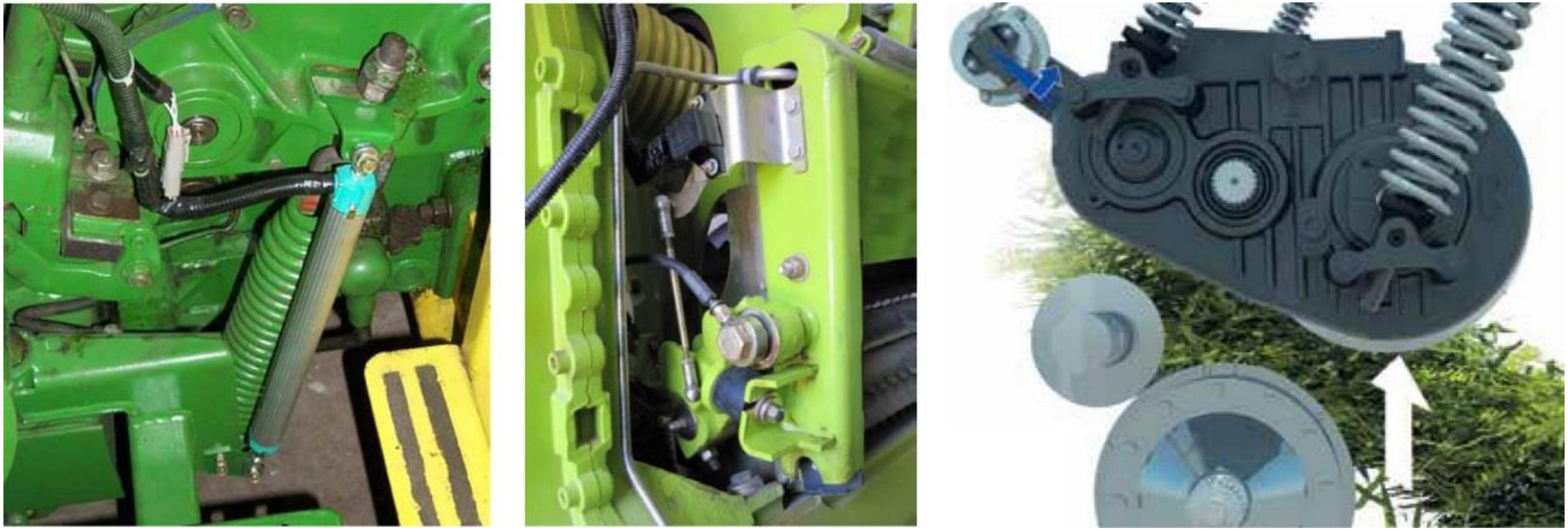


Forage harvester yield measuring principle based on feer roll displecement with a rocker linked to upper press roll of forage harvester (Ehlert, 2002).



Forage harvester equipped for forage yield mapping.

- Instantaneous throughput measurement system based of measurement of the distance between feeder rolls of the harvester is only commercially available today.
- This system is offered in various forms e.g. by John Deere, Claas, New Holland or Krone Co.
- It is probably a good compromise between price, simplicity and accuracy of the measuring system.



Sensors measuring the distance of the feed rollers by John Deere (left), Claas (center) and New Holland (right). Corporate literature, modified.

Demmel (Schröder et al., 2008, Heege et al., 2013) reported that sensor errors in the material throughput of various forage harvesters, according to various authors, vary between 2.7% and 5.9% in different systems, with accuracy a commercially used system based on the principle of measuring the distance of the feeder rolls moves at the upper limit of this interval (Ehlert, 1999; 2002).

Calibration of forage harvester's yield monitor

(according to Digman and Schinners, 2012)

- As in the case of combine harvesters, to build a yield map, forage harvester's electronics combine mass-flow (throughput), harvested width, speed and location.
- Harvested width, speed and location are available from the machine's global navigation satellite system.
- Throughput on a forage harvester is commonly measured indirectly as feed roll displacement.
- Because throughput is not directly measured, a calibration that builds a relationship between feed roll displacement and throughput is critical.

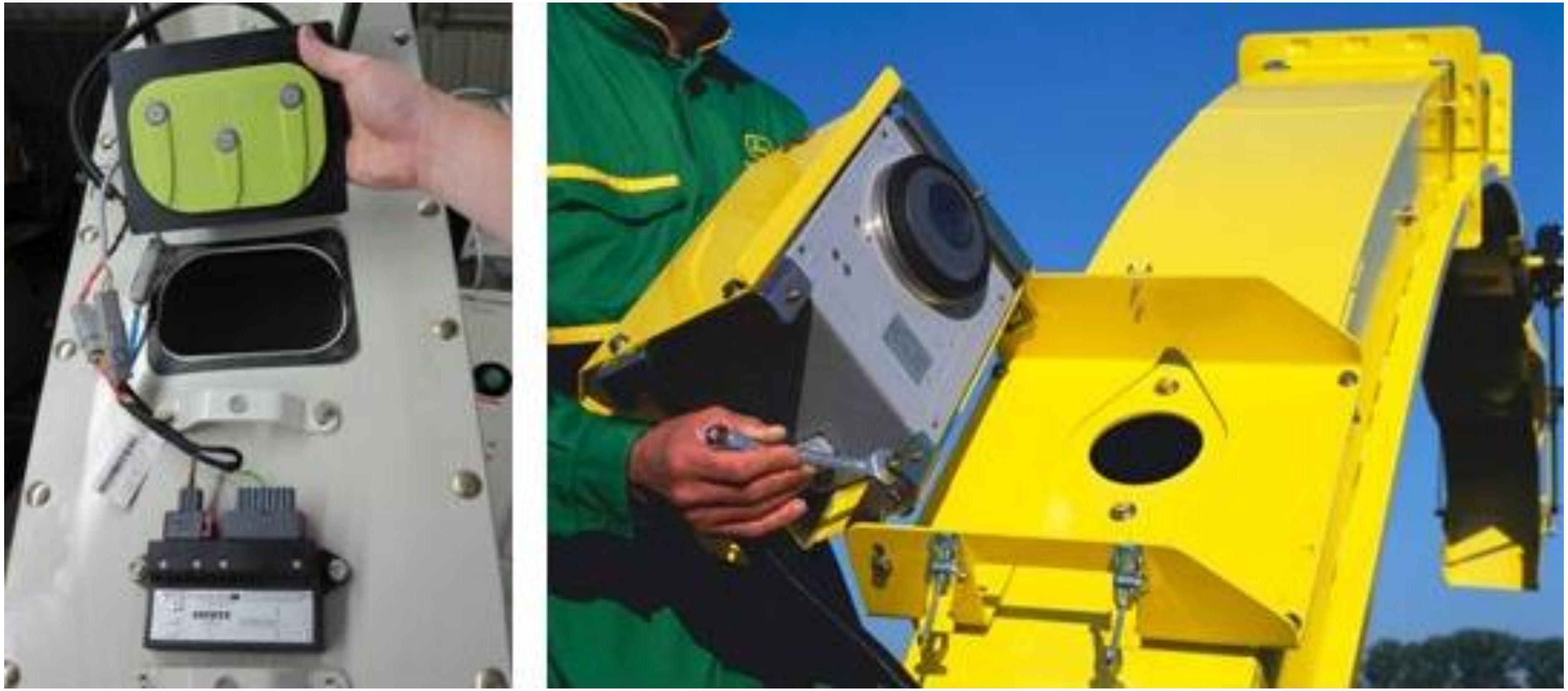
- Calibration begins with ensuring the feed rolls start at the proper zero position.
- Consult operator’s manual for specific points to check on your machine and for specific steps for the zero point calibration.
- Be sure to check that your machine is set up for the crop you intend to harvest.
- Once 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 you are harvesting.

- Crop yield, moisture and species, as well as fee droll spring tension and length of cut, can have a significant effect on the yield prediction.
- It is important to start the calibration process in a representative, uniform area of the field.
- It is also important to harvest at the speed you expect to operate (to ensure that the calibration point is as close to the typical operating conditions as possible).

Calibration itself

- Follow the steps recommended by the manufacturer.
- Make sure that container you are loading has a recent empty weight and that it is completely empty.
- Harvest a full load; in order to obtain an accurate calibration factor, do not overfill the container (harvesting losses).
- Most machines allow the operator to resume harvest until the load weight can be entered into the calibration wizard.
- Calibration factor is than calculated: relates container weight to calculated volume during calibration run (based on fee droll displacement and time to fill the container).
- Calibration factor adjusts yield data recorded from this point forward.
- It is recommended to adjust calibration factor at least once per day or when a noticeable change in harvesting conditions occurs.

Forage moisture sensors



Forage harvester moisture sensors. Left capacitance (Claas). right near infra red (CNH).

Calibration of forage harvester's moisture sensor

- Both of the above sensors work on different principles need to be cleaned of material buildup, especially gummy material, to work properly.
- Both require a call to the dealership if moisture prediction is significantly off.
- Capacitance sensor accuracy can be improved by entering a crop density (compressing harvested crop into a specific volume container and measuring the weight).
- For the NIR sensor, make sure your sensor has the latest calibrations from the manufacturer.
- Make sure that sensor's lens is free of any scratches or excessive wear and is properly adjusted to interact with the harvester's crop stream.

Mowing machines

- Belt weighing technology in the windrowing device (Demmel et al., 2002)
- Torque requirements in the windrowing device (Ruhland et al., 2004)
- Pulse radar system measured crop layer thickness in the windrowing device (Wild et al., 2003)

Mower-conditioner equipped with belt weighing technology (Demmel et al., 2002)

Mower-conditioner equipped with belt torque measurement device (Ruhland et al., 2004)

Material feed rate sensors suitable for pulled rotary mowing machines equipped with conditioner

- Conditioner's power requirement measured by torque-meter (Kumhála et al., 2001)
- Material change in momentum measured by a curved impact plate (Kumhála et al., 2007)

Devices for the measurement conditioner power input (right) and harvested material change in momentum by curved impact plate (left).

However, none of these systems is used in practice today. There are several reasons:

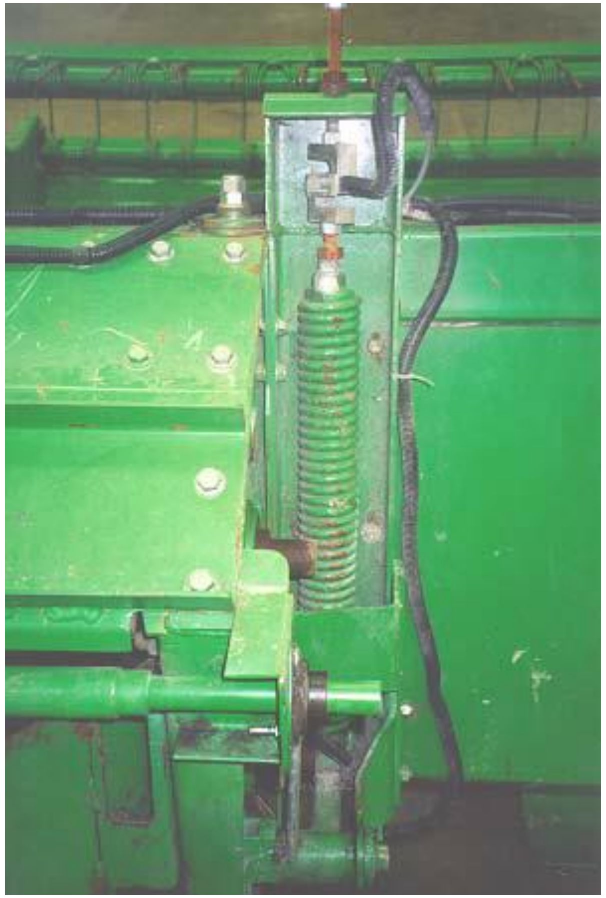
- forage crops are very inhomogeneous and therefore complicated in terms of throughput measurement,
- technical solutions are not universal enough (some systems can only be implemented to machines with a belt conveyer row compiler),
- most of these methods are based on contact principles,
- the price of measuring systems is still high compared to the price of the machine.

Mowing machine ZTR 186 equipped with yield mapping system.

Self-propelled forage windrower

- Impact force on the swath shield (Shinners et al., 2000)
- Rotary potentiometers to measure crop volumetric flow (Shinners et al., 2003)

Shinners, Barnet and Schlesser (2000) measured mass flow rate at self-propelled forage windrower by different methods.



Measurement of conditioning roll spring force. This system was able to predict mass flow rate with coefficient of determination 62%.

Measurement of conditioning roll rise. This system was able to predict mass flow rate with coefficient of determination 59%.

Measurement of swath shield impact force. This system was able to predict mass flow rate with coefficient of determination from 83% to 90%.

Pendulum-Meter (Crop-Meter)

- Pendular sensor attached in the front of a tractor was introduced by Ehlert et al. (2004).
- With forward motion of the tractor, the pendular is guided through the canopy in a defined height and moves in accordance with the resistance of the plants.
- The degree of deflection of the pendular depends mainly on the mass of the plants.

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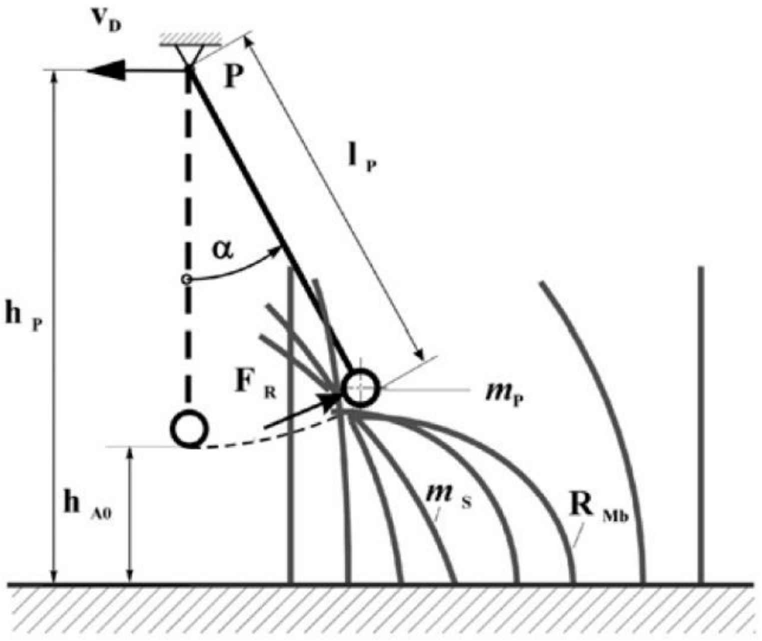
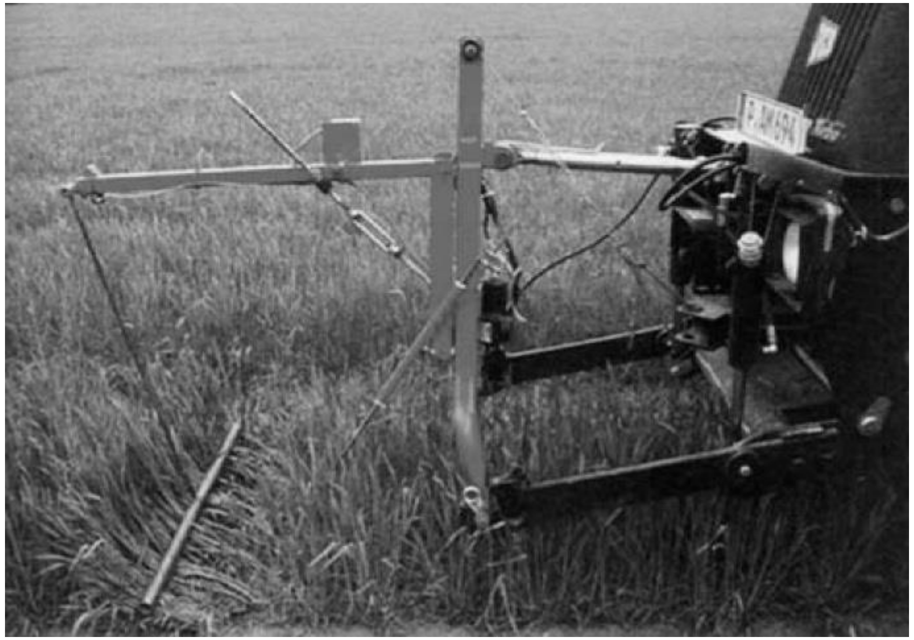


P	- Pivot point
α	- Angle of deviation
F_R	- Resultant force
h_P	- Height of pivot point
h_{A0}	- Height of pendulum (α=0°)
l_P	- Length of pendulum
m_S	- Mass of stems including mass moment of inertia
m_P	- Mass of pendulum
v_D	- Driving velocity
R_{Mb}	- Bending moment of resistance

$h_A = h_P - l_P \cos\alpha$

Measurement principle of the pendulum meter



Pendulum meter attached at tractor front three point hitch

Practical example of pendulum meter function

Thank you very much for your attention!

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