5. LESSON

YIELD SENSORS FOR POTATOES AND SUGAR BEETS – ROOT CROPS YIELD SENSORS

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 root crops:

Potatoes

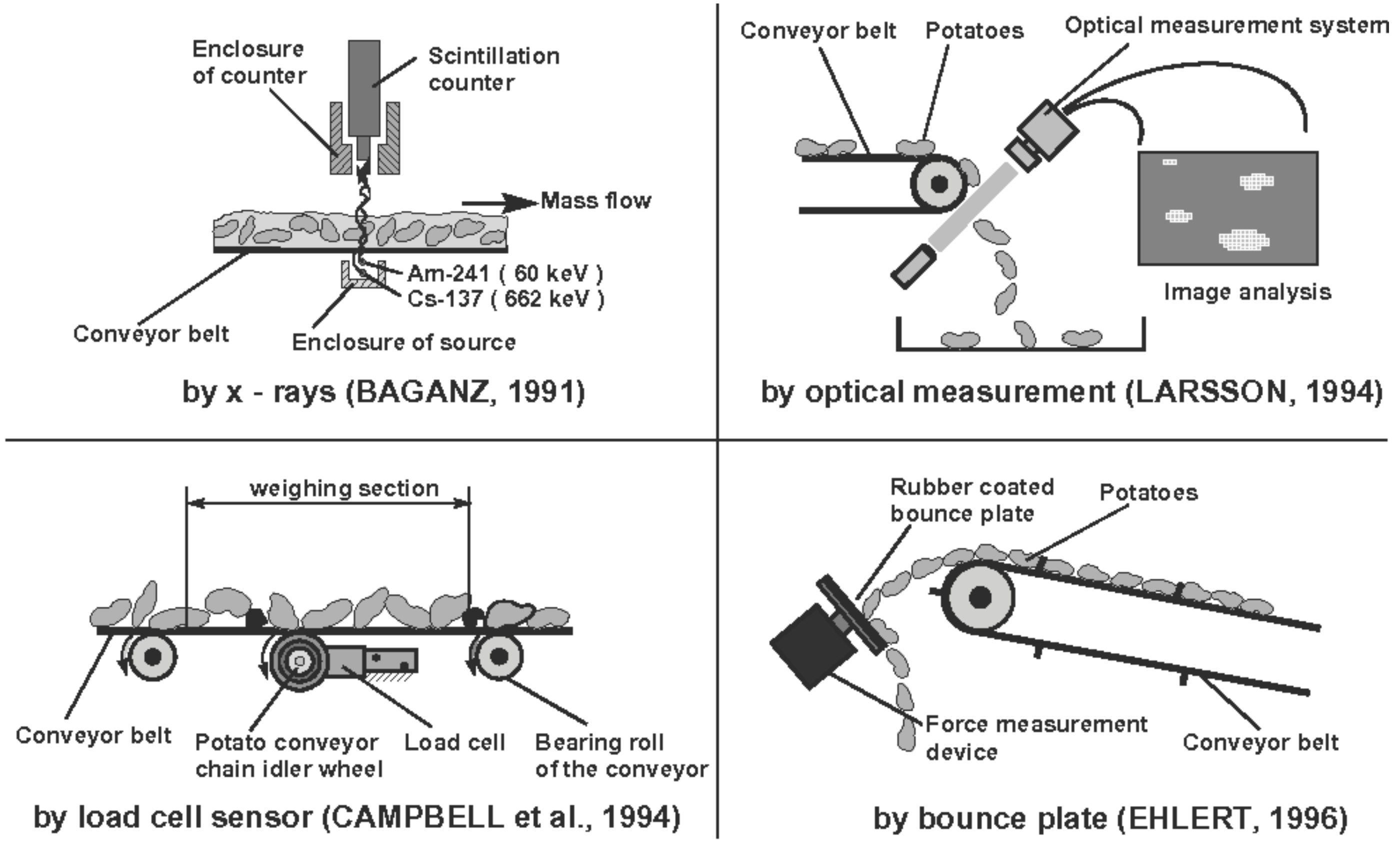
Sugar beet

Root crops yield monitoring

In order to measure the immediate yield of root crops, under CR and central Europe conditions mainly potatoes and sugar beet, a number of different measurement principles have been tried in the past, which have been integrated into different types of harvesters.

Potatoes

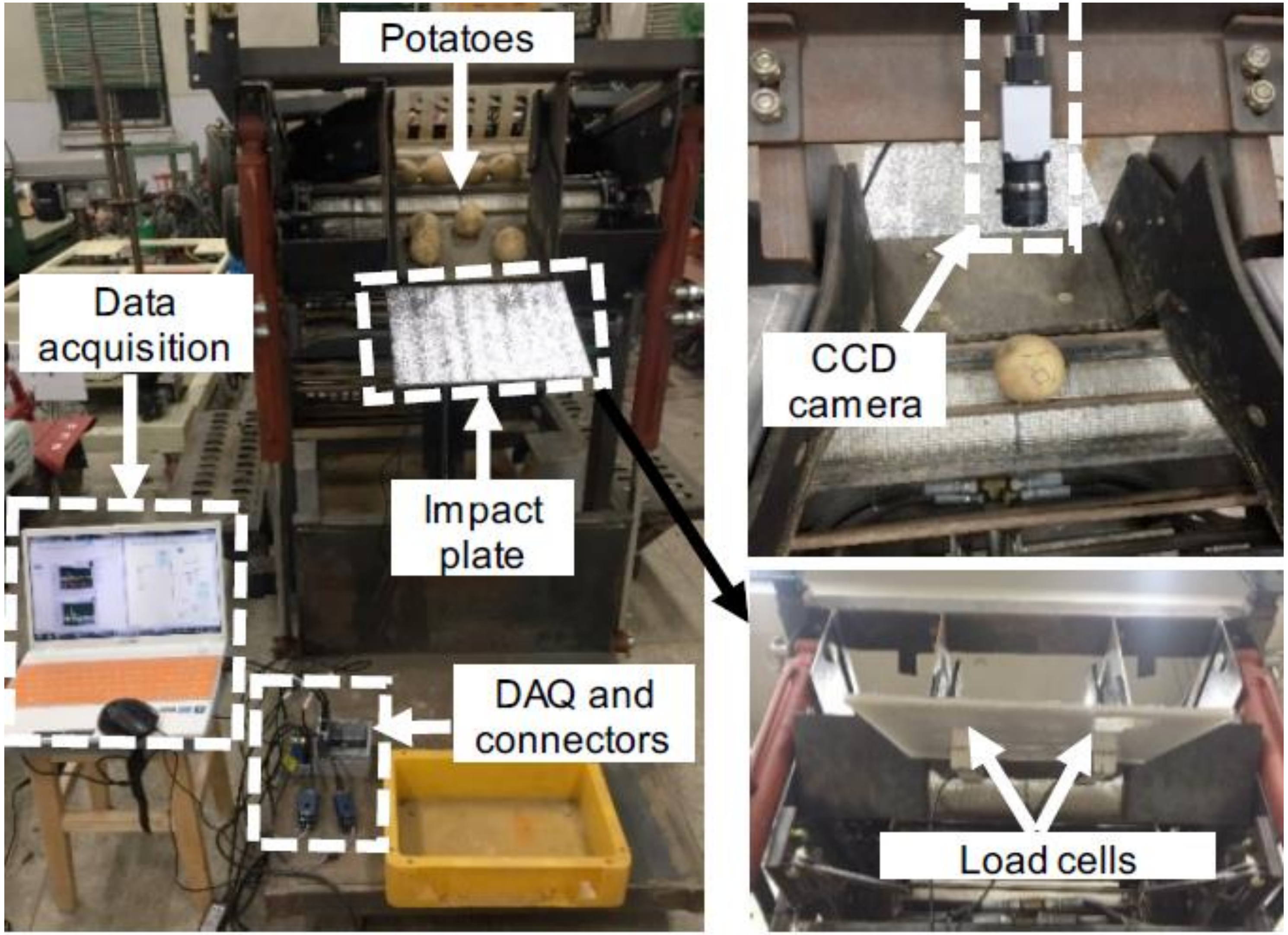
- DeHaan et al. (1999) developed a system based on weighing of a portion of potato conveyer in a harvester with the trade name HarvestMaster. A similar system is also tested by Mostofi et al. (2007)
- Ehlert and Algerbo (2000) gave a short overview of possible potato throughput measurement principles. Radiometric measurements, weighing cells in the continuous conveyor belt, optical measurements with photo evaluation, and deflection plate measurements were all known techniques.
- Gonigeni et al. (2002) developed an image-based system for sweet potato yield and grade monitoring.
- Hofstee and Molena (2002) tested a machine vision based yield mapping system of potatoes and recently, (Hofstee and Molena, 2003) they used a similar system for estimation of volume with potatoes partly covered with a soil residue.
- Persson et al. (2004) developed an optical sensor for tuber yield monitoring.



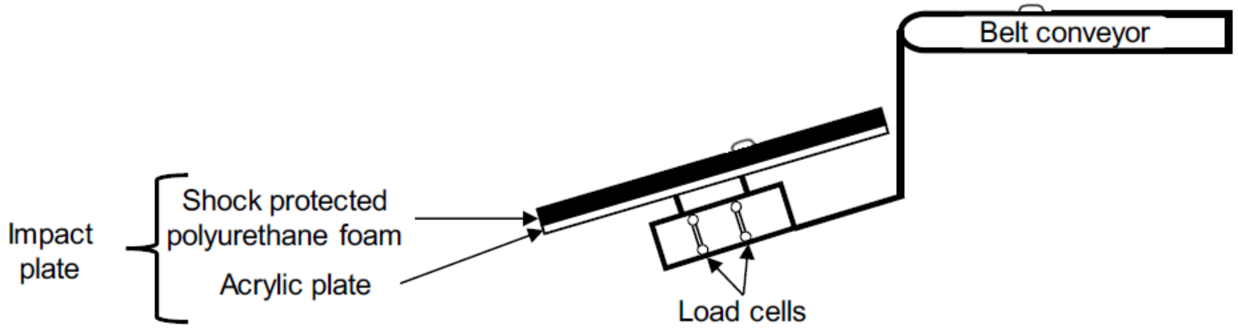
Principles of potato yield mapping by Ehlert (2004)

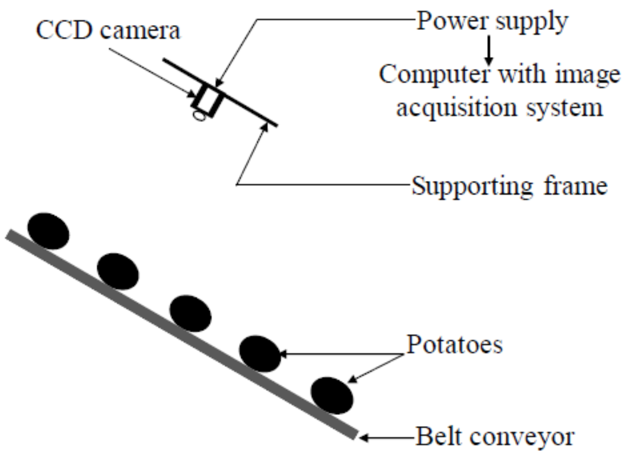
Load cells, sometimes called strain gauges, look like rectangular steel bars with mounting holes and are easy to install on a harvester's conveyor frame. They are usually positioned toward the back of the conveyor frame where potatoes are cleanest, and they support a section of the belt.

Weighing systems can be easily mounted on various types of conveyors for potato and beet harvesters.



Kabir et al (2018) compared mass based (impact plate) and volume based (CCD camera) potato yield monitoring systems of small-sized potato harvesters. Under laboratory conditions, they obtained encouraging results.





Arrangement of the impact plate and load cells for sensing weight of potatoes

Arrangement of the volume based yield sensing of potatoes

Sugar beet

- Weight sensing systems have been studied in several applications (Isensee and Lieder, 2001; Schwenke et al., 2002; Walter and Backer, 2003; Hall et al., 2003).
- Schmittmann and Kromer (2002) tried to measure the mass flow of clean beet. They based their method on online counting of beets and calculating specific yield by multiplying the number of beets the average mass of single beets.
- Hennens et al. (2003) developed a mass flow sensor for sugar beet harvesters based on the use of a curved impact plate to measure momentum. Sensor was tested on two machines, Agrifac ZA EH 215 and Dewulf R6000T.
- Konstantinovic et al. (2007) evaluated an ultra wideband radar system for sugar beet yield mapping. They tried to distinguish sugar beet and its dimensions from the surrounding agricultural soil.

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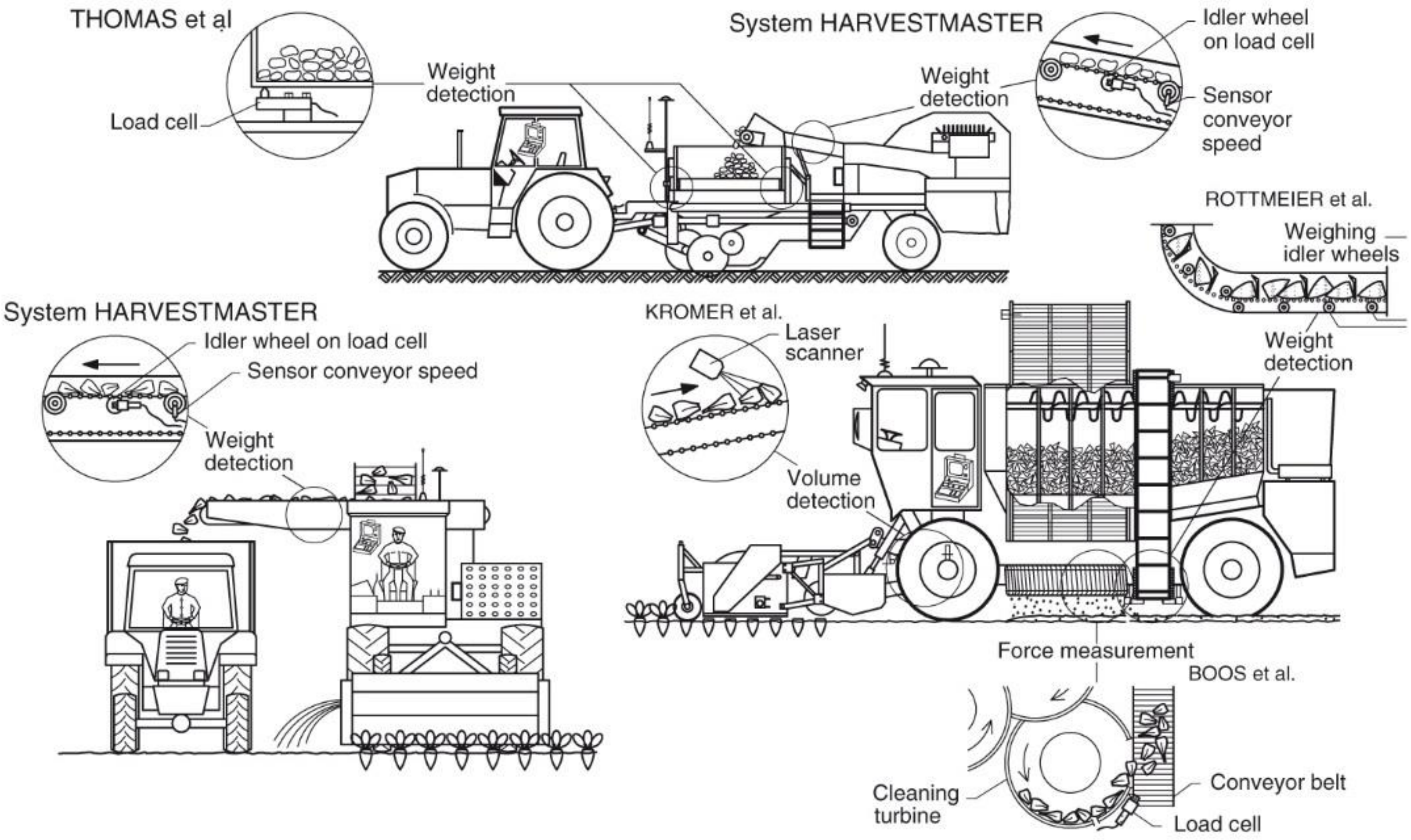
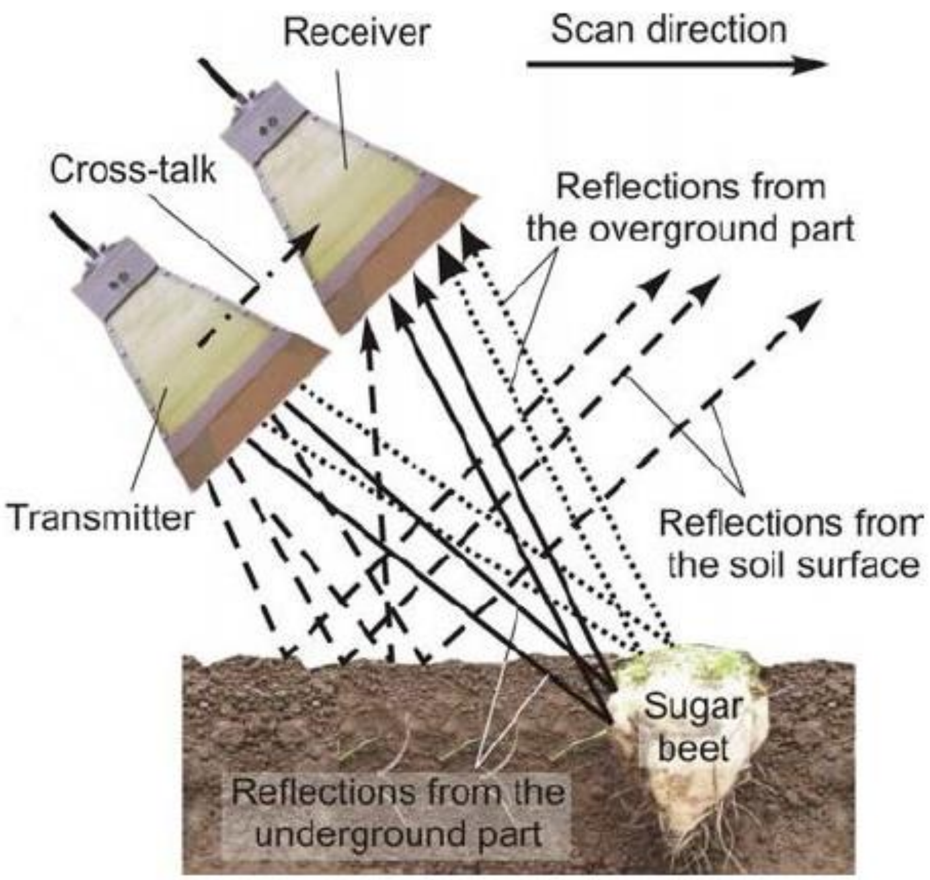


Sensor applications to determine mass flow and yield in root crop harvesting equipment according to Demmel (in Heege et al., 2013).



Principle of ultra wideband radar system for sugar beet yield mapping introduced by Konstantinovic et al. (2007).

Demmel (Schröder et al., 2008, Heege et al., 2013) assessed the accuracy of some of the above principles:

- weighing systems (conveyor weighing, Harvestmaster or pulley weighing) range from 2.2% to 5.6%,
- friction compensated curved impact plate showed a 1.6% error,
- sugar beet laser optical volume sensor up to 4% .

In practice, probably the most widespread root crop mapping system was the HM 500 system from HarvestMaster (conveyor weighing in the harvester using a loose pulley mounted on strain gauges). However, the company also stopped manufacturing it.

Accordingly, there is no commercially available system for measuring the yield of root crops on the market. Reasons for it:

- root crops are grown on relatively uniform and flat fields,
- first generation of sensors was implemented into the technological process of existing machines (many compromises had to be made - negatively affected both the accuracy and functionality),
- accuracy of the sensors, especially in often difficult harvesting conditions, should be improved and stabilized,
- the functionality of the sensors must be simplified, especially calibration.

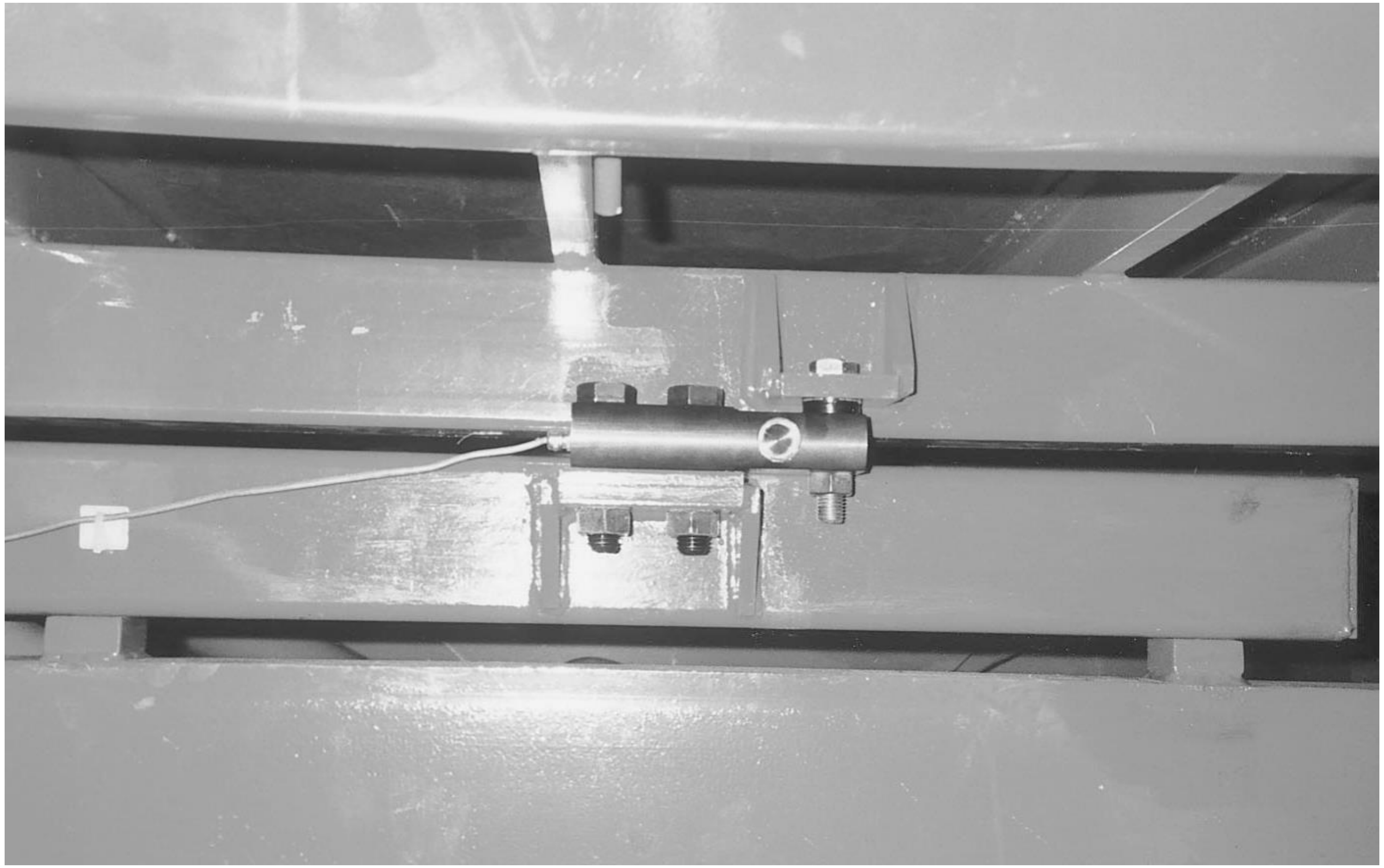
Measurement of mass accumulation rate

A versatile, and at first glance, a relatively simple method of measuring the instantaneous throughput of different crops to produce yield maps is continuous weighing – transport wagons, bins (tanks, bunkers) placed on a machine, or e.g. round balers.

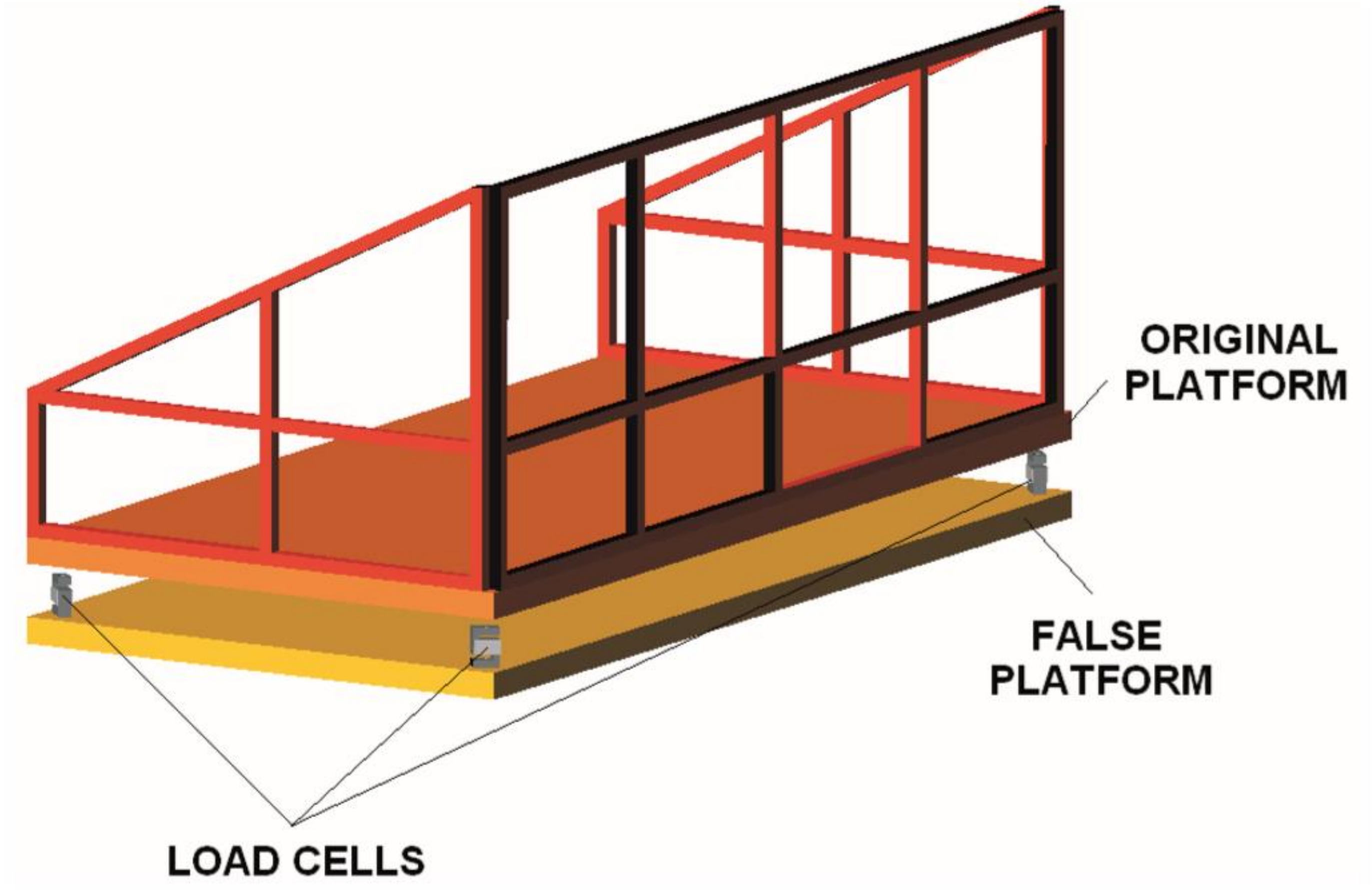
Godwin et al. (1999) unbuckled the 20 t tractor trailer and hung it on strain gauge sensors. The trailer could be continuously weighed. Such as modified trailer was used to transport potatoes, chopped maize and sugar beet.

The system worked satisfactorily, an error of up to about 4% was observed in potato or beet harvesting.

A similar system has also been tested by Lee et al. (2002) or Saldaña et al. (2006).



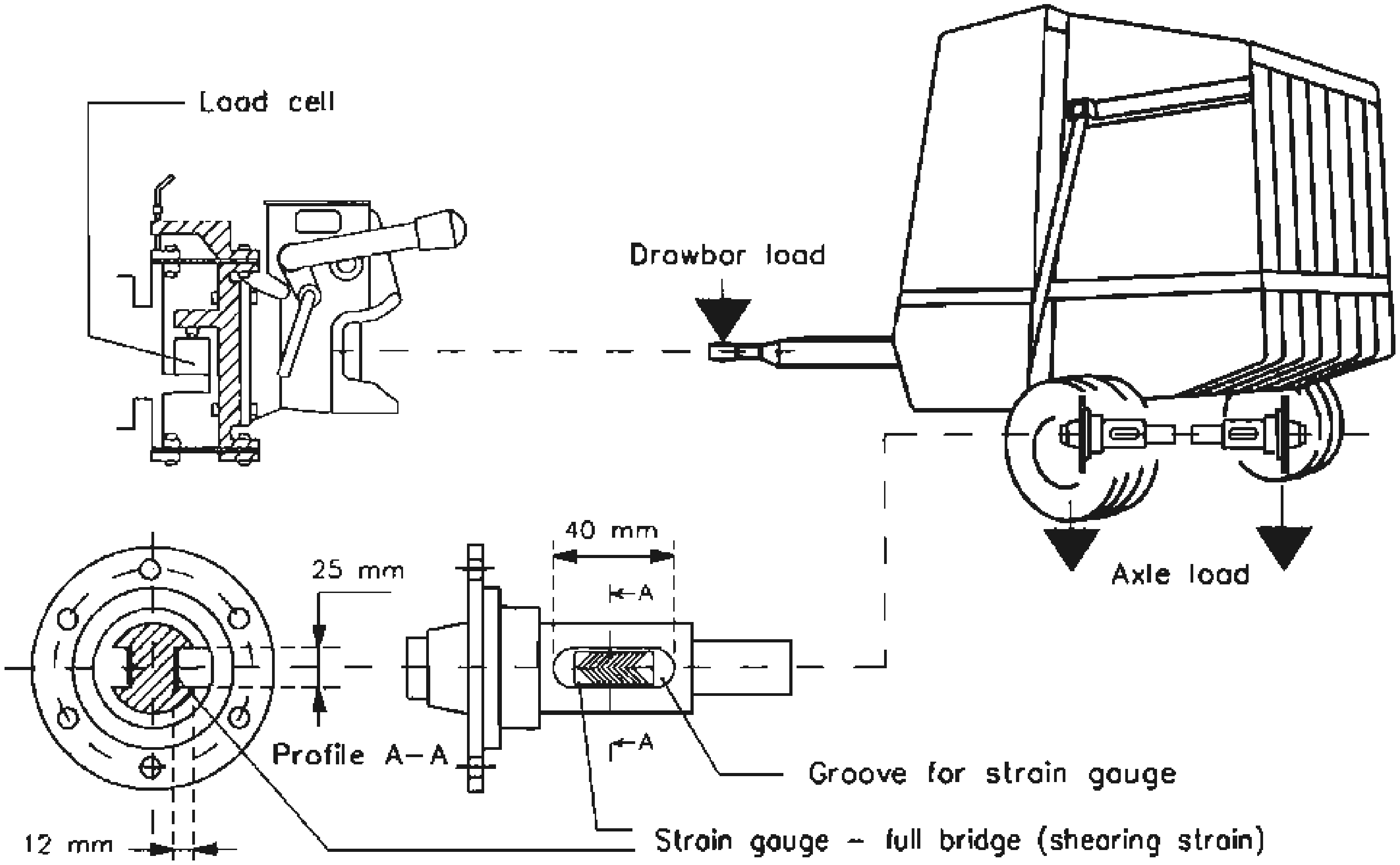
View of one of the strain gauge sensors located on the tractor trailer. Godwin et al. (1999).



Saldaña et al. (2006) used similar system for vegetables yield mapping.

Continuous weighing of round balers.

- Similar to the body of a tractor trailer, the baler can also be continuously weighed.
- Measurements were made by authors in both America (Behme et al., 1997) and Europe (Wild and Auernhammer, 1997; 1999).
- Baler must be equipped with strain gauges again located in the drawbar and baler wheels. These places make up all three points of support.
- Wild and Auernhammer (1999) reported that the accuracy of the cylindrical baler weighing system under operating conditions was up to ± 10%.



Arrangement of round baler for continuous weighing (Wild and Auernhammer, 1999) .

Integrated bale weighing system itroduced by Claas.
The exact bale weight is displayed on the terminal of the QUADRANT models during working and saved for further use.

Problems generally associated with the principle of continuous weighing

- Ratio between the weight of the container (trailer, bin, tank, bunker) and the weight of the increment is too large. Strain gauges must be able to support the weight of the full tank. Resulting error could be relatively high for that reason.
- Serious problems are caused by vibrations. There are usually two basic sources of vibration on the machine. One source is associated with the operation of engine and with technological process of the machine (conveyer movement, etc.). These oscillations are mostly harmonics and can be removed. Another source of vibration is associated with the machine's travel, for example, on an uneven surface. Such oscillations are not harmonious and can only be removed with difficulty.

Problems generally associated with the principle of continuous weighing

- Example: round baler weighing system achieved better results when the machine was working with under-inflated wheels.
- Another problem is admixtures (e.g. soil, dust, stones, dirt, etc.), which of course are also weighed together with the observed plant material.

Thank you very much for your attention!

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