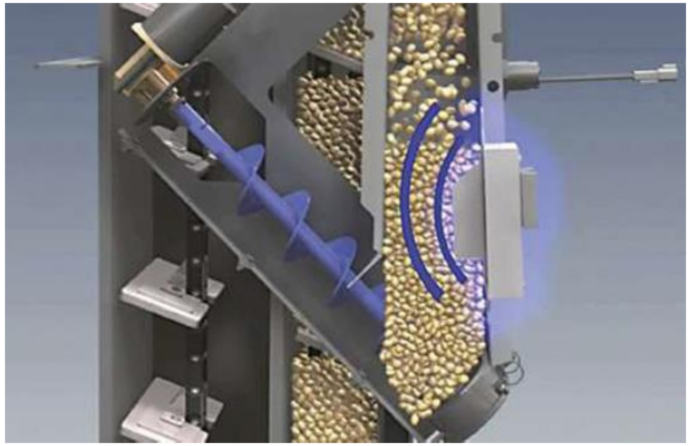
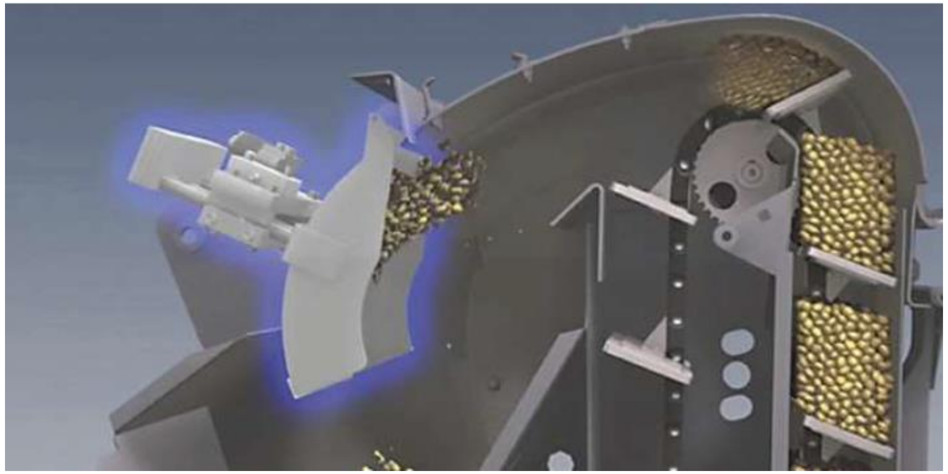
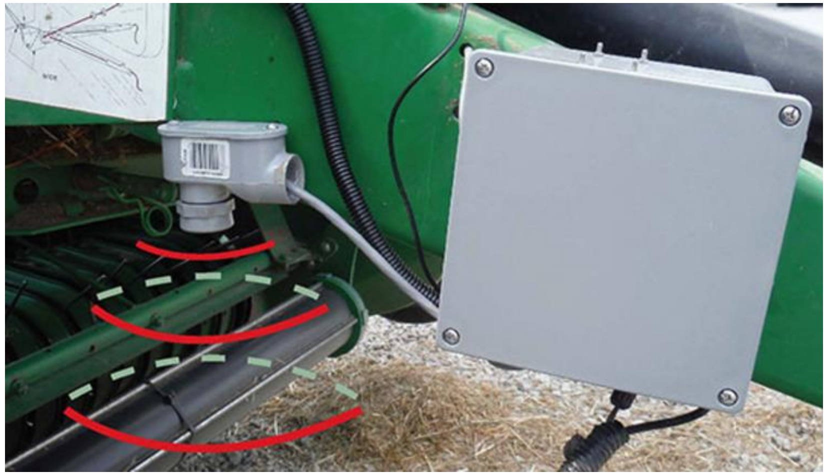
1. LESSON

YIELD SENSORS – BASIC OVERVIEW




The idea of yield mapping was born in the US in the 1980s.

The GPS positioning system, developed by the US Army, started to be available also for civilian applications.

Someone thought that combining information about the machine's current position and immediate yield would result a yield map.

Yield mapping systems first appeared in combine harvesters because of two main reasons:

1. Combine harvester is an expensive machine, and the yield mapping system increases its price relatively little
2. Cleaned grain is very uniform material, which is very advantageous for the work of yield sensors

Two essential information are necessary for yield mapping:

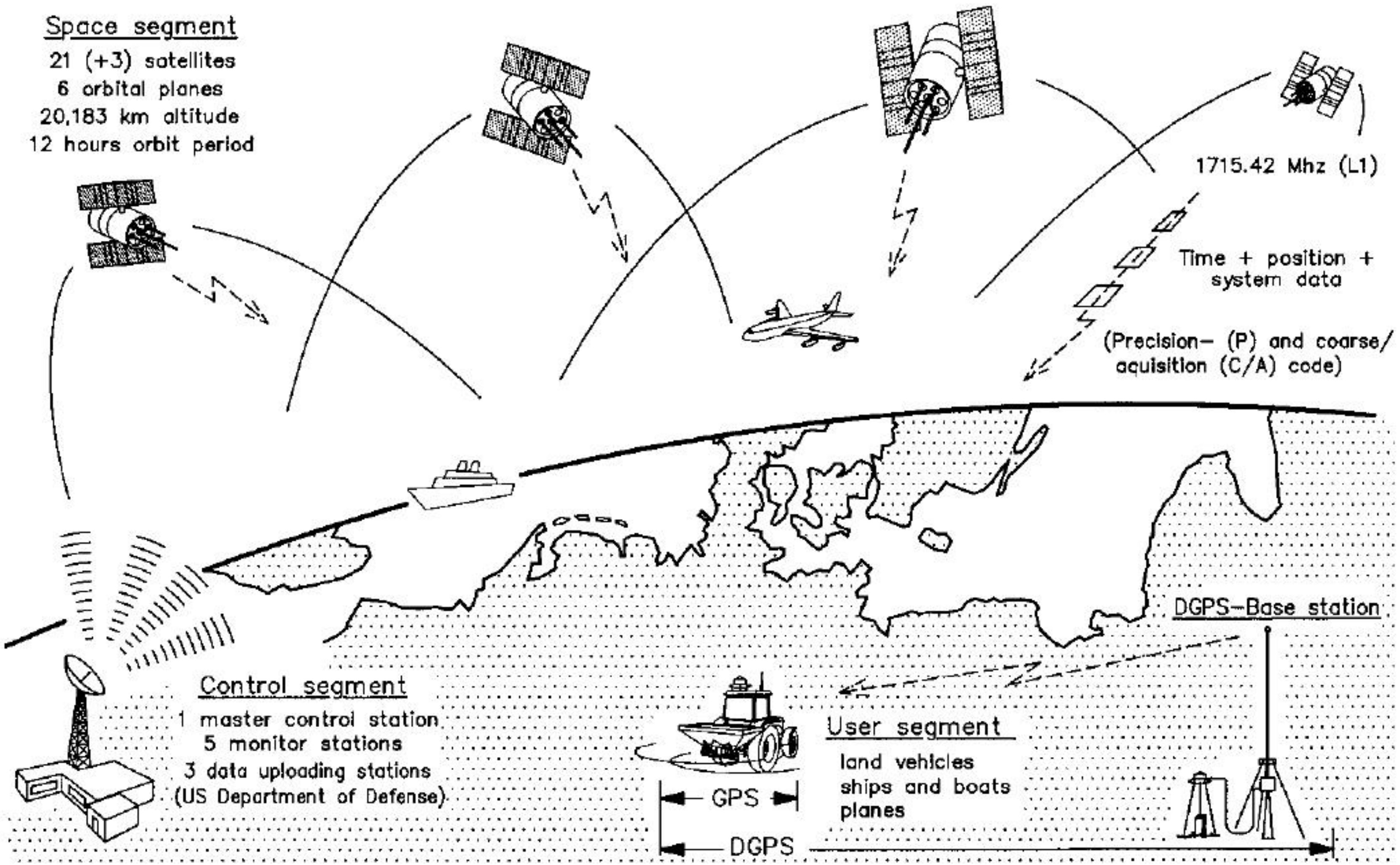
Information about instantaneous yield

Yield sensor

Information about machine´s current position

DGPS signal receiver

Information about machine´s current position



Also:
Glonass (Rus)
Galileo (EU)
Beidou (China)

Measurement of instantaneous moisture content of harvested grain

Grain moisture sensors are important feature of the yield monitors:

- Overview of the instantaneous moisture of the harvested grain (can vary from 10 to 15% during the day)
- Allow the grain weight to be converted to standard moisture (14%)

Grain moisture content is usually measured by sensors working on capacitance principle. Moisture has a significant effect on the permittivity of the grain and its changes can be measured by changing the capacitance of the capacitor.

Yield map and its importance for precision agriculture

- Basis for decisions about field cultivation
- Checking the results of previous field management (differentiated fertilization, plant protection, sowing, etc.)
- Comparison of historical development of yields on field
- Possibility to create yield frequency map
- Verification of remote sensing information
- Shows economic results of cultivation of individual parts of the field

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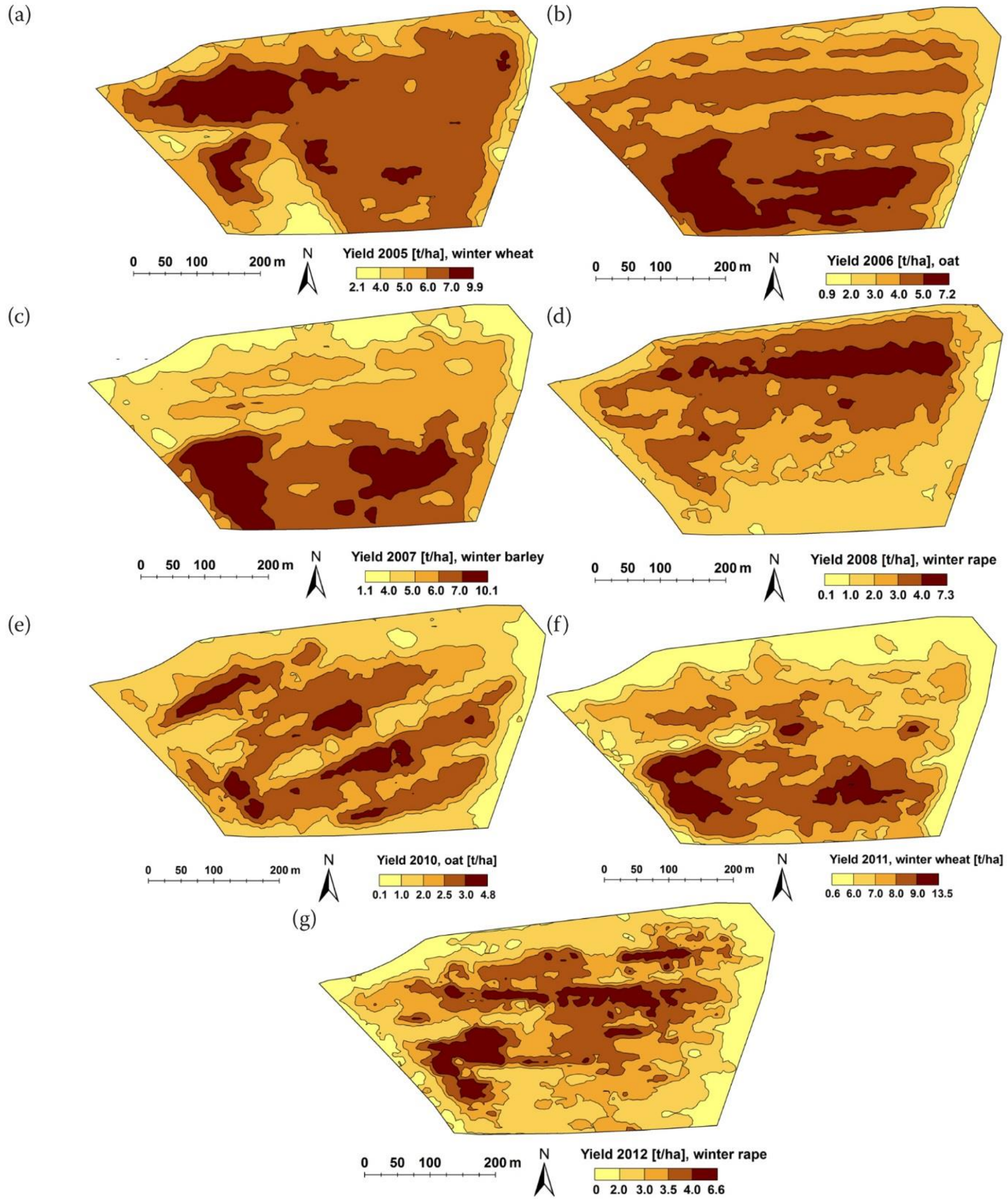


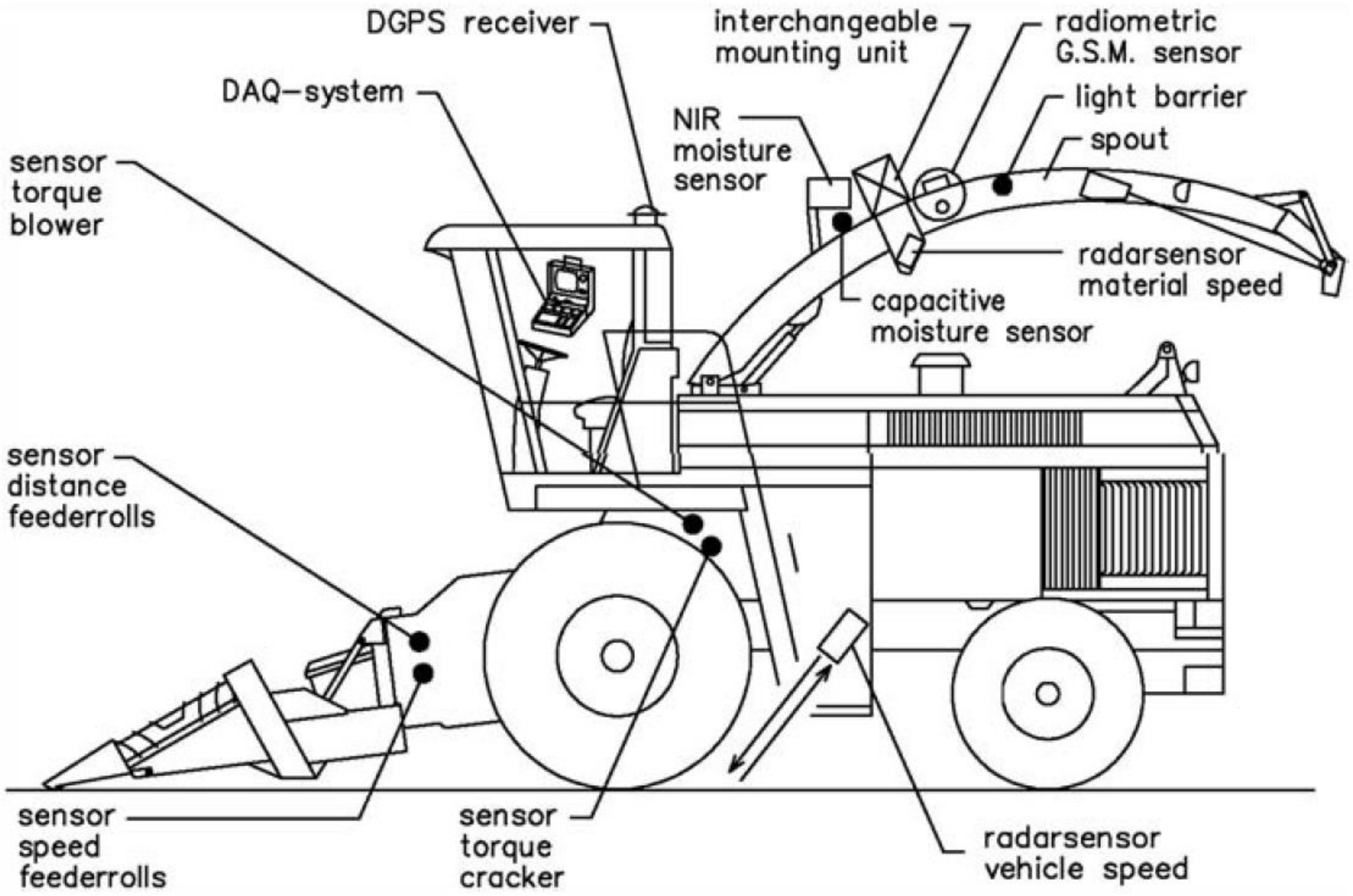
Yield development in years on one field. Crop rotation: 2005-winter wheat, 2006-oat, 2007-winter barely, 2008-winter rape, 2010-oat, 2011-winter wheat, 2012 winter rape.

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.

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.



Forage harvester equipped for forage yield mapping.

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)

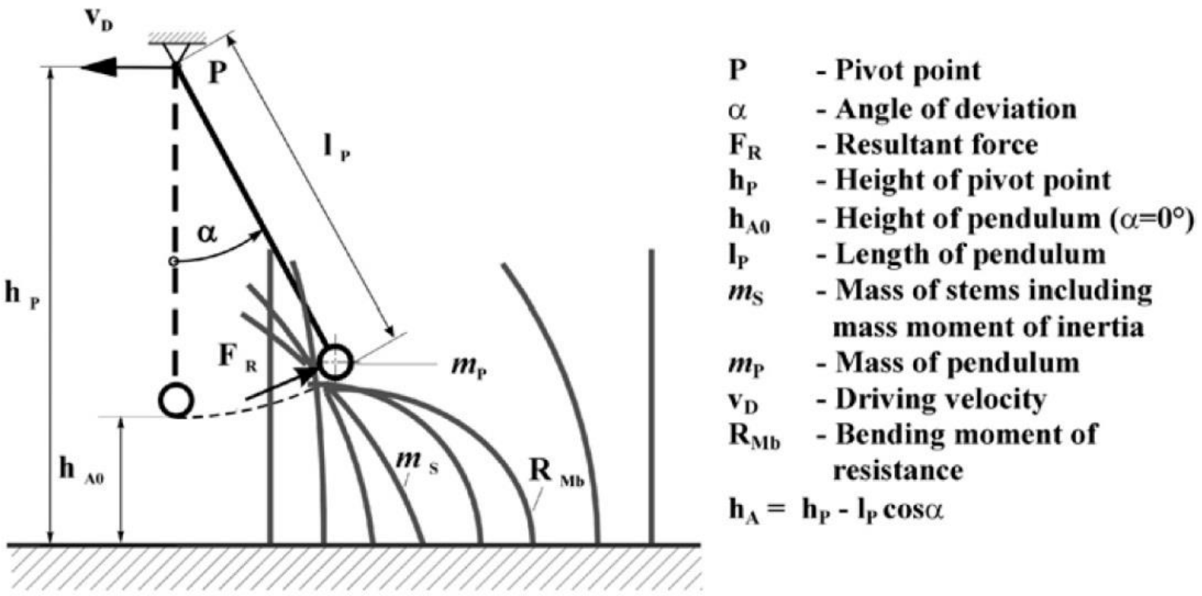
Devices for the measurement conditioner power input (right) and harvested material change in momentum by curved impact plate (left).

Self-propelled forage windrower

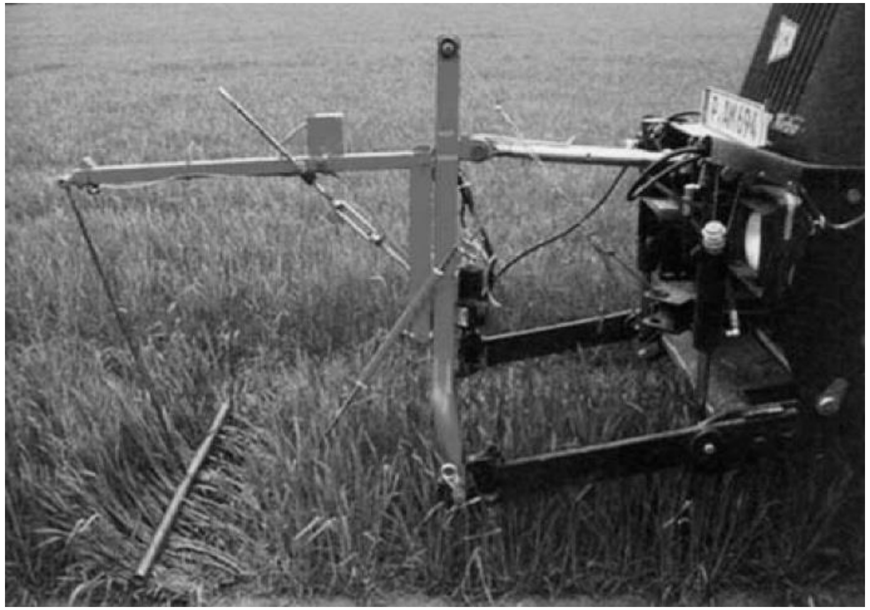
- Impact force on the swath shield (Shinners et al., 2000)
- Rotary potentiometers to measure crop volumetric flow (Shinners et al., 2003)

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.



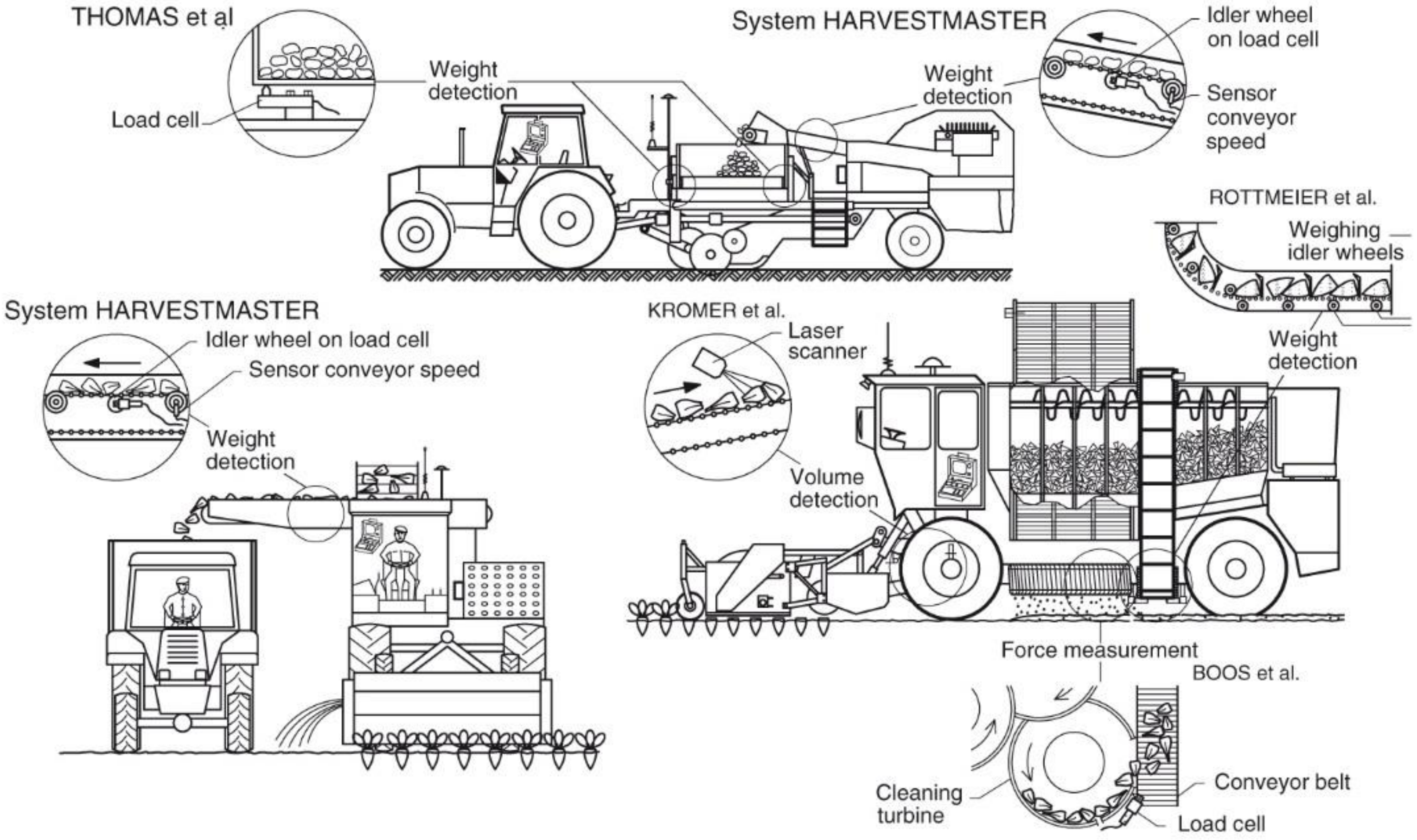
Measurement principle of the pendulum meter



Pendulum meter attached at tractor front three point hitch

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.



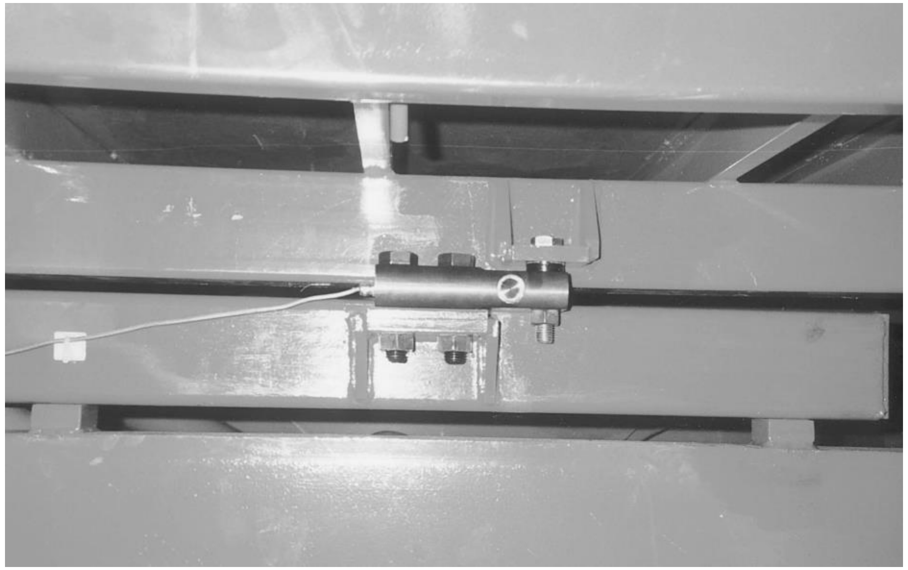
Measurement of mass accumulation rate

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).

Evaluation of Forage Yield Map Techniques on a Mowing-conditioning Machine

Mowing machine was equipped with electronic measured unit and DGPS signal receiver.

The mowing machine's conditioner shaft was fitted with a torque-meter.

Besides the torque-meter, the mowing machine was equipped with a curved impact plate mounted at the exit of the machine.

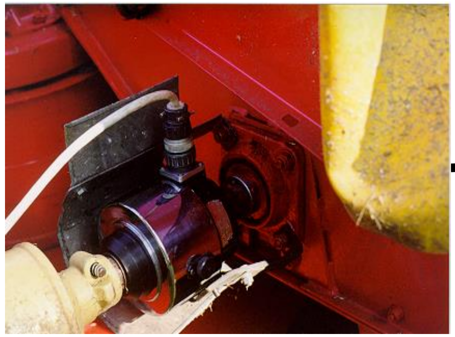
Measurement devices

DGPS receiver

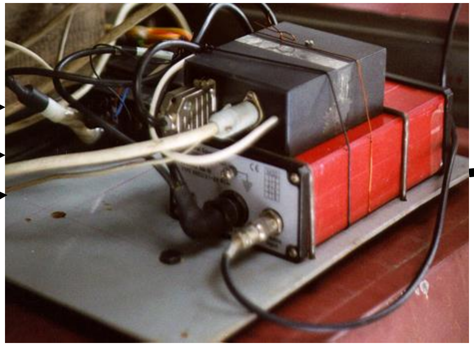
Antenna

Impact plate

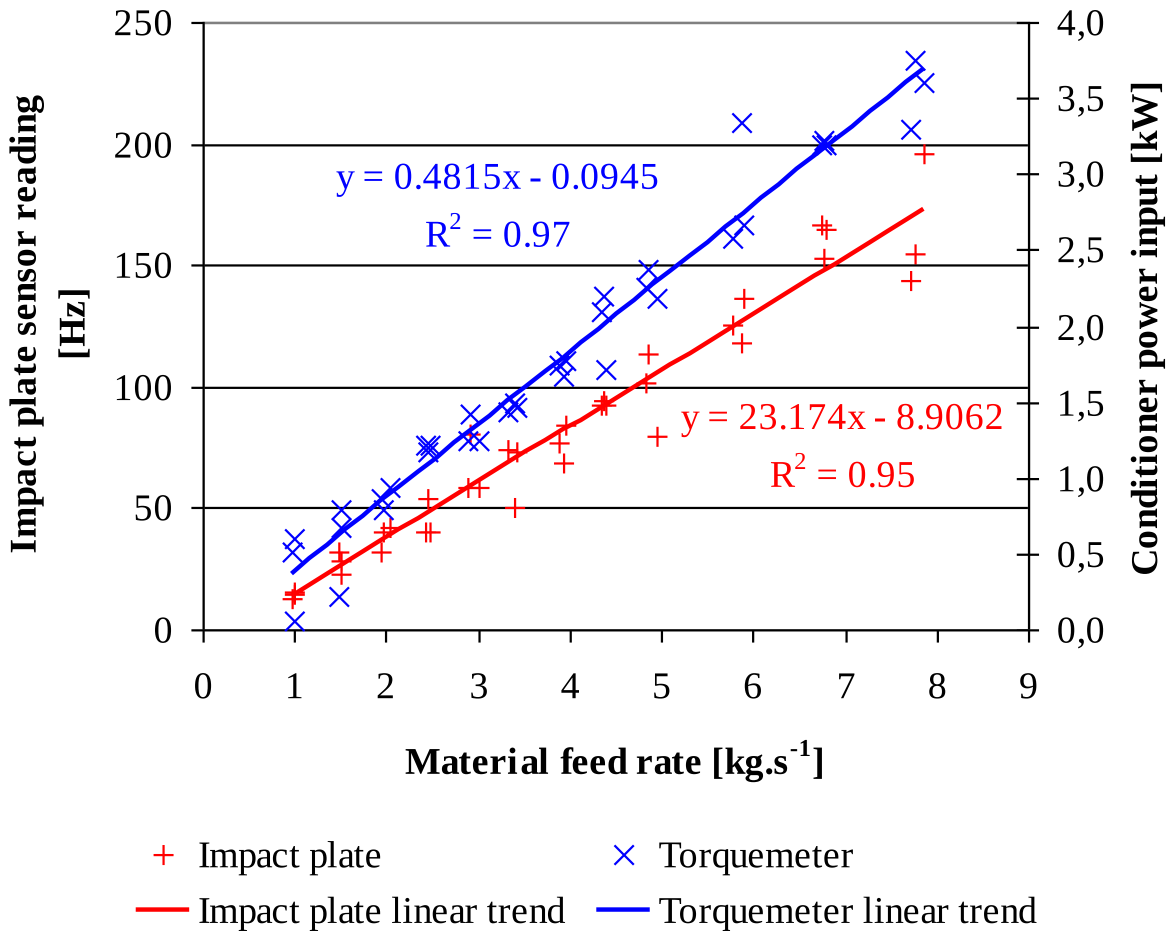
Torque-meter



Microcomputer



PC (notebook)



Dependence of conditioner's power input and output frequency of the apparatus measuring the impact force on material feed rate.

Exists a good linear relationship between conditioner's power input, output frequency of the apparatus measuring the impact force by means of the impact plate, and material feed rate through the mowing machine.

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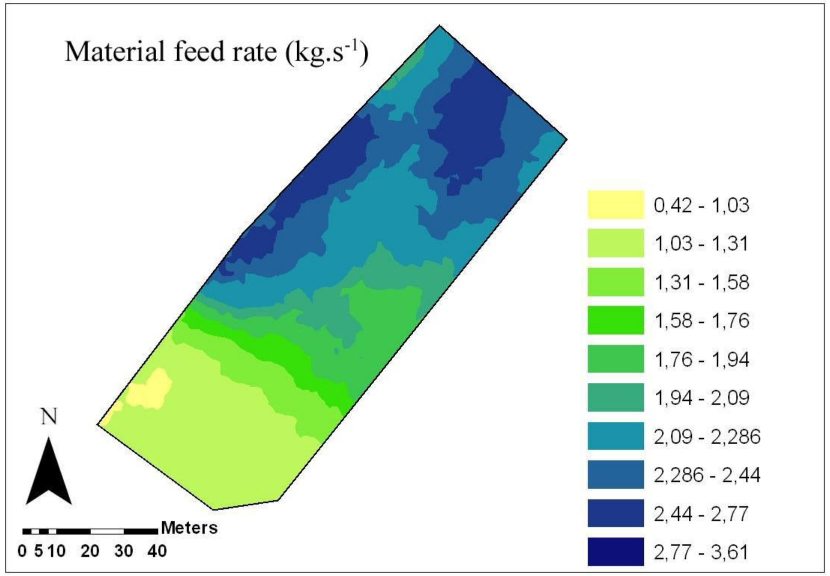
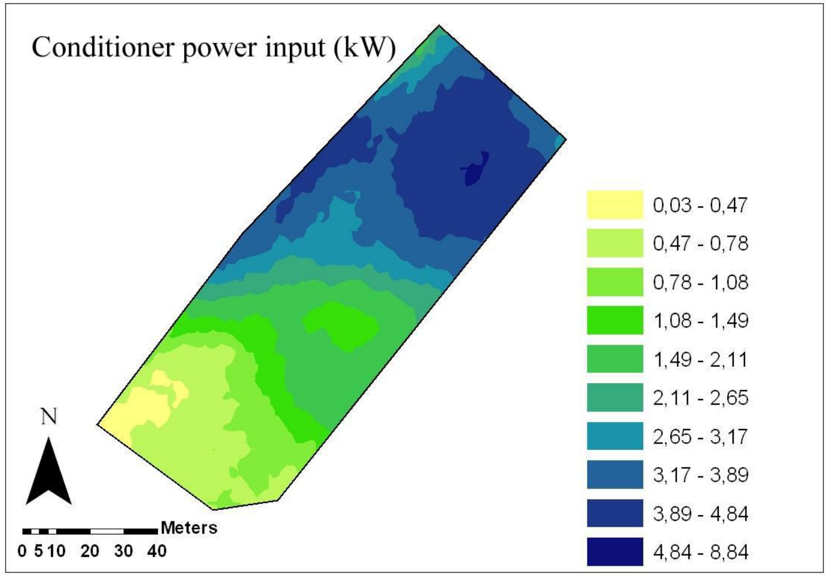
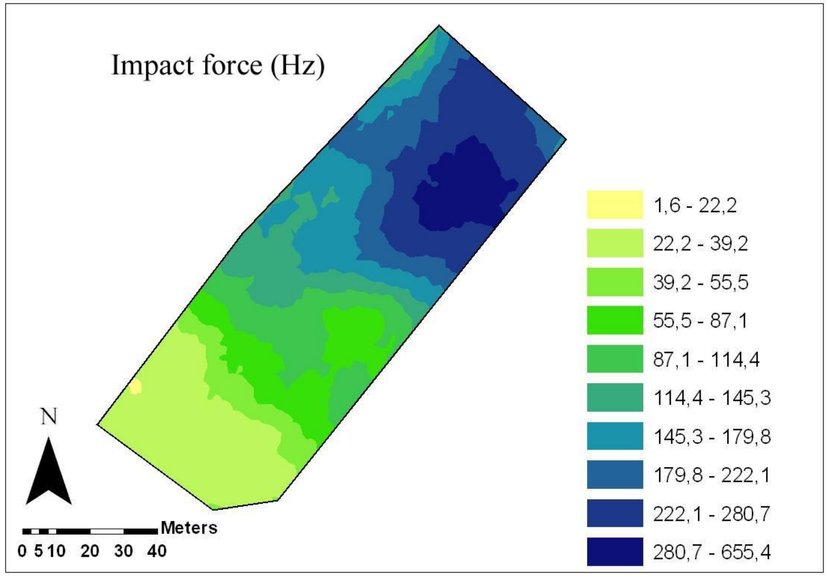






Visualisation of the data distribution was shown by the maps (plotted using the Kriging method). Similarities between the map of conditioner power input and material feed rate and between the map of impact plate sensor reading and material feed rate were found. The results showed that both principles of material feed rate measurement can be used for grass yield map creation under real field conditions.

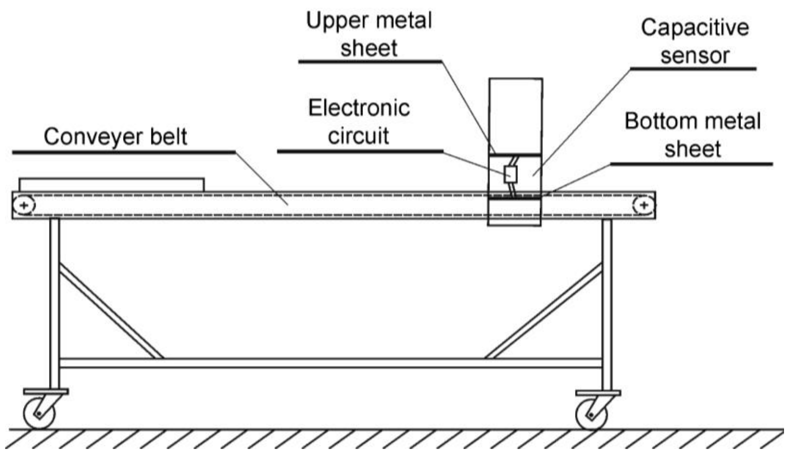
Capacitance sensor techniques can be used for the determining different properties (moisture content etc.) of a range of plant materials.

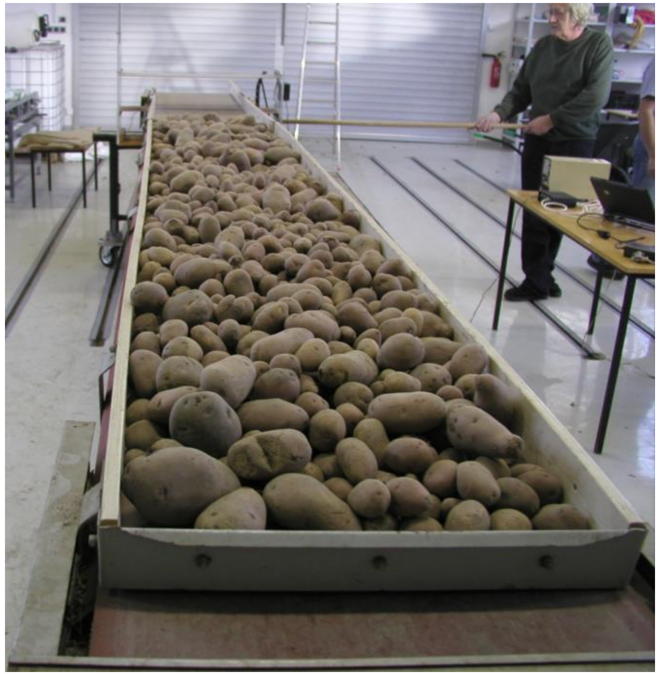
The function of capacitance sensors depends on the fact that the dielectric constant of an air/material mixture between two parallel plates increases with material volume concentration increasing.

Parallel plate capacitance sensor:

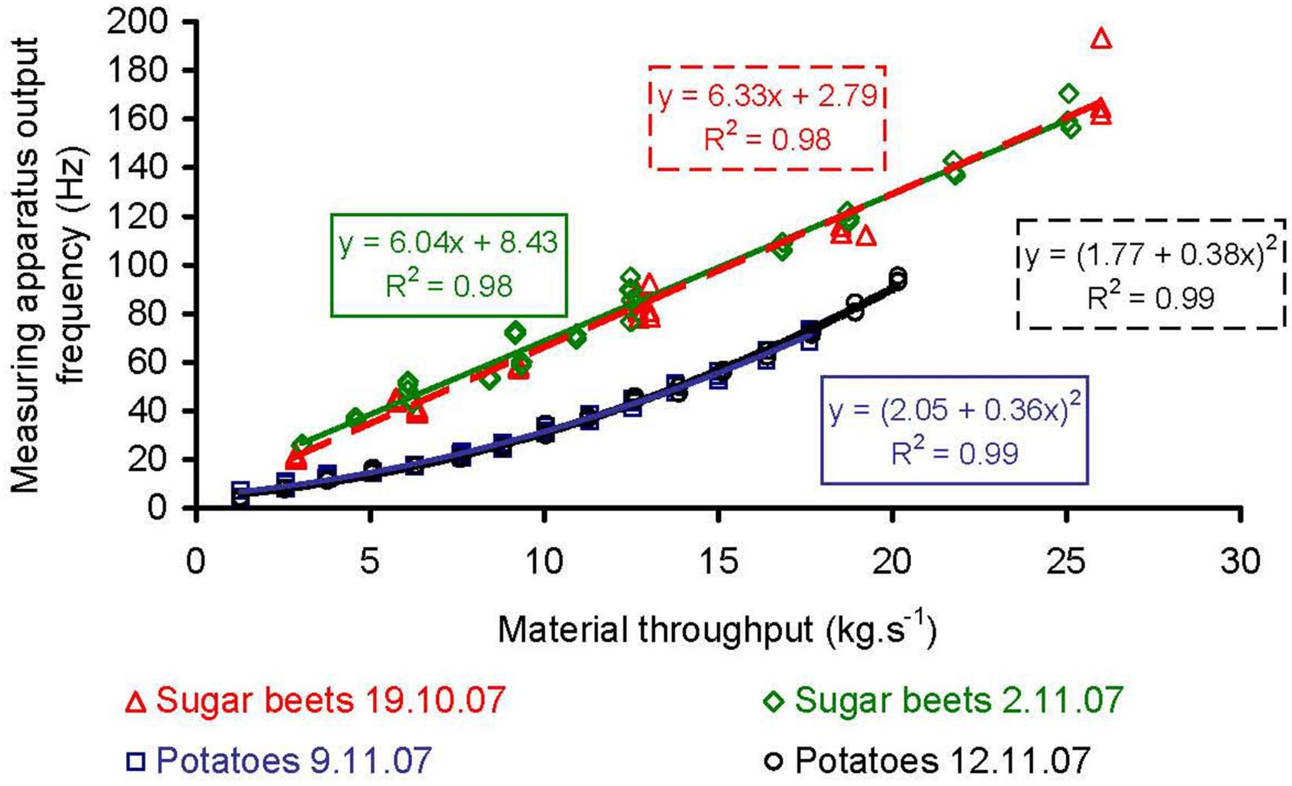
- two metal sheets 2 mm thick (830 x 260 mm)
- 180 mm distance
- sides - 10 mm thick acrylic glass
- sensor was driven at 27 MHz frequency.

Experiments with sugar beet and potatoes





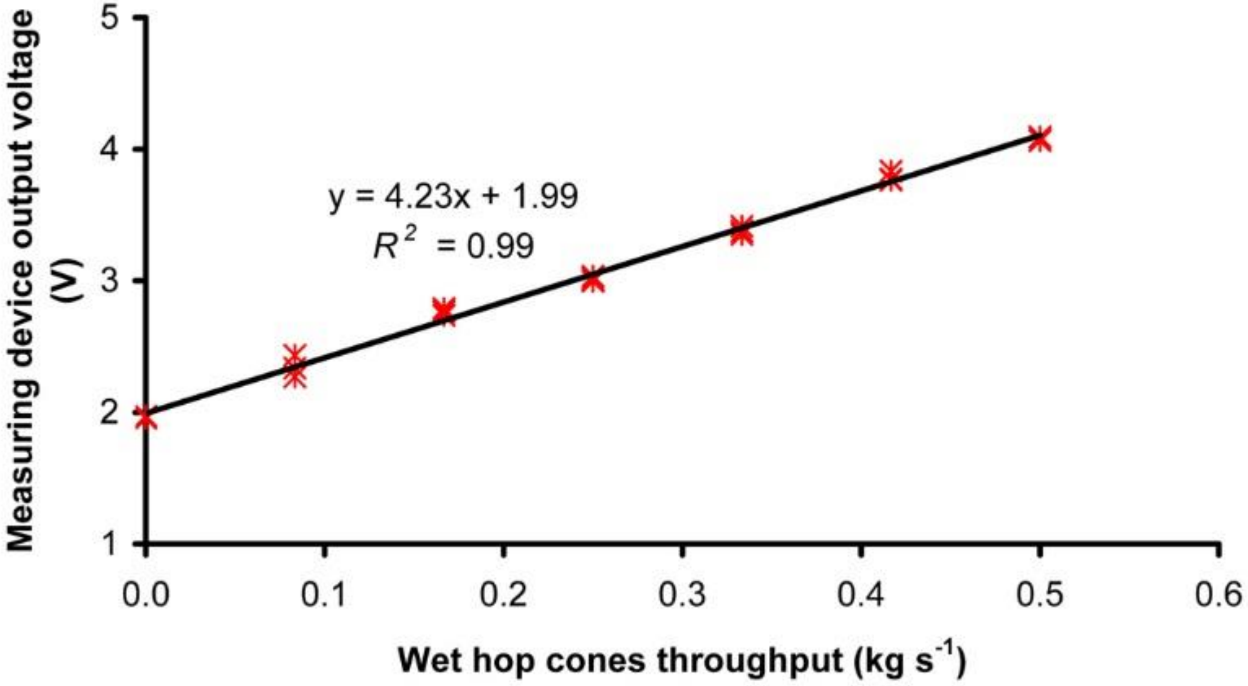
Arrangement of measurement device for laboratory tests after improvement was used. Capacitor plates distance 180 mm.



Dependence of measuring apparatus output frequency (directly proportional to voltage and sensor capacity) on sugar beets and potatoes throughput.

Capacitive throughput sensor was tested also with freshly shopped maize.

Another measurements were arranged with wet hop cones.



Location of capacitive throughput unit on the stationary hop picking machine PT-30 (highlighted by white rectangle).

Dependence of measured capacitive throughput unit output voltage on wet hop cones throughput under real harvesting conditions – calibration curve. Rubín hop variety, moisture content (wet basis) 75.6%.

Control unit integrated to PT-30 hop picking machine.

View of the graphic touch operator panel when the hop picking machine is in operation. In this case, the operator used the manual controls. The conveyor speed was set to 60% of the maximum speed.

Thank you very much for your attention!

František Kumhála