AGRO/MSYM/AGEN 431

Principles of Yield Mapping

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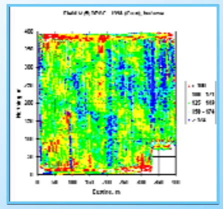
Yield Mapping

"Yield mapping refers to the process of collecting georeferences data on crop yield and characteristics, such as moisture content, while the crop is being harvested."

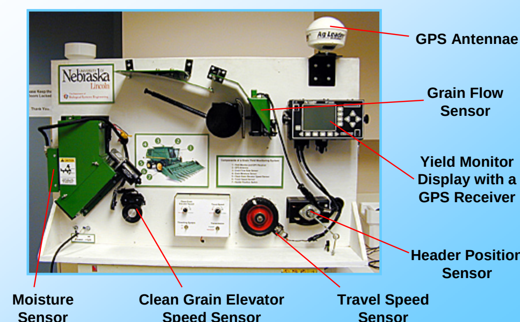
(National Research Council, 1997)



Crops and Agricultural Material

- Corn
- Soybeans
- Wheat
- Sugar beets
- Rice
- Hay
- Cotton
- Corn silage
- Peanut
- Straw
- Potato
- Tomato
- Carrot
- Grape
- Fruit

Grain Yield Monitor Components



Yield Monitor Concept

$$Yield = K \cdot \frac{Flow \cdot Time}{Width \cdot Length}$$

Yield = crop yield (bu/acre)

Flow = grain flow (lbs/s)

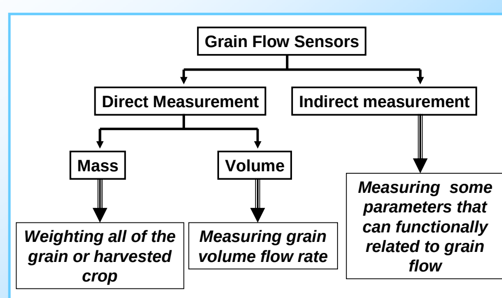
Time = recording time interval (s)

Width = swath width (in)

Length = distance travel during recording time (in)

K = 112011 (corn) or 104544 (soybeans and wheat)

Measurement of Grain Flow



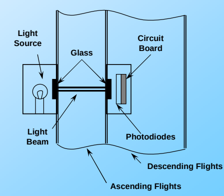
Direct Volume Yield Sensor

- Measuring the height of the grain on individual flights of the clean grain elevator
- Measuring grain flow through the sensor mounted on the discharge side of clean grain auger
- Measuring the volume flow of grain leaving the grain bin auger by counting revolutions of a rotating paddle system, in which each compartment contains a fixed volume of grain
- Measuring volume changes in the grain bins on combines

Pierce et al. (1997)

Sensing Grain Volume on Individual Elevator Flights

A beam of light, projected across the clean grain elevator, is used to sense the grain height on individual flights. Multiple diodes, located in a line opposite the light source, sense the time periods when grain was moving past the sensor location and also provide information about the surface contour of the grain on each flight.

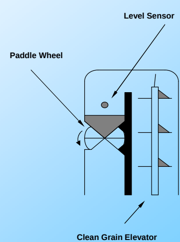


Accuracy ± 3 %

Hummel et al. (1995)

Claydon Yield Monitor

This instrument counts the number of times a paddle wheel rotates to transfer the grain to the clean grain auger. A head of grain is maintained above the paddle wheel and no grain passes without its rotation. The paddle wheel, which rotates in response to grain reaching the level sensor, is driven directly by the harvester's power system, and its rotation is relatively constant.



Accuracy ± 1 %

Murphy et al. (1995)

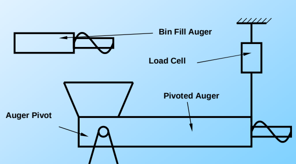
Direct Mass Yield Sensors

- Pivoted auger flow sensor
- Triangular elevator
- Mobile platform scale in the clean grain cross auger
- Weighting conveyor (potato yield monitors)
- Weighting table (tomato yield monitors)

Pierce et al. (1997)

Pivoted Auger Flow Sensor

An auger is mounted with one end pivoted and the opposite end supported by a load cell. Grain flows from the existing clean grain auger into the pivoted end and travels through the auger to be discharged to the grain tank.

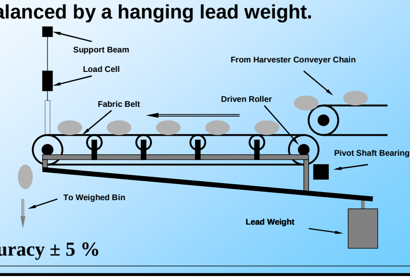


Accuracy ± 3 %

Borgelt (1993)

Potatoes Yield Monitor

Potatoes transported on the belt are weighted with an electronic load cell which supports one end. The other end pivots on a bearing mounted shaft. Most of the unloaded weight of the conveyer is counter balanced by a hanging lead weight.

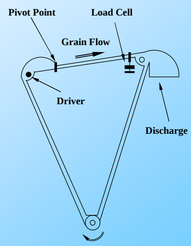


Accuracy ± 5 %

Rawlins et al. (1995)

Triangular Elevator Yield Sensor

The additional sprocket created a third horizontal leg in the elevator. The grain entry end of horizontal section was supported by a simple pivot, while the grain discharge end was supported by a load cell.



Accuracy ± 5 %

Schrock et al. (1995)

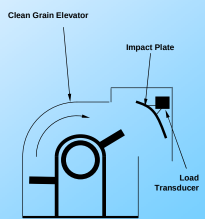
Indirect Measurements

- Mass flow measured with momentum plate (a sensor plate or set of fingers installed near the top of the clean grain elevator)
- Attenuation of radiation between a source and a detector
- Capacitance plates mounted around the discharge auger tube
- Kernels on piezo-film mounted underneath the combine sieve
- Voltage across a shunt on a DC motor that is used to drive the clean grain system

Pierce et al. (1997)

Impact Plate

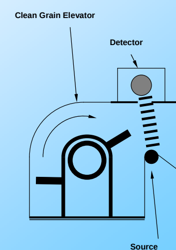
The weight of grain leaving clean grain elevator is assessed through the measurement of momentum transferred from discharged grain to an impact plate. Elevator speed measurement is used to calculate grain mass flow. Multiple rates calibration is critical.



Accuracy ± 5 %

Radiation Attenuation Sensor

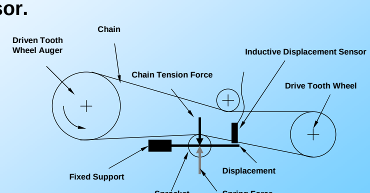
A gamma source (Americium 241) is mounted below the flow of grain leaving the clean grain elevator. The attenuation of the radiation between the source and the detector is a stable function of the mass of the grain.



Accuracy ± 1 %

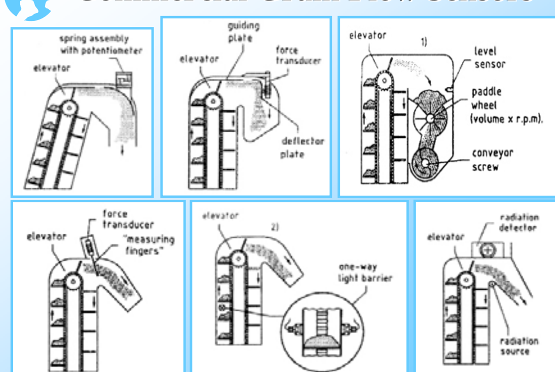
Straw Yield Sensor

The sprocket, mounted on two springs, is loaded by the force at the pull side of the chain depending on the torque needed to drive the auger in the header of combine. The displacement of the springs are measured by means of a linear inductive distance sensor.

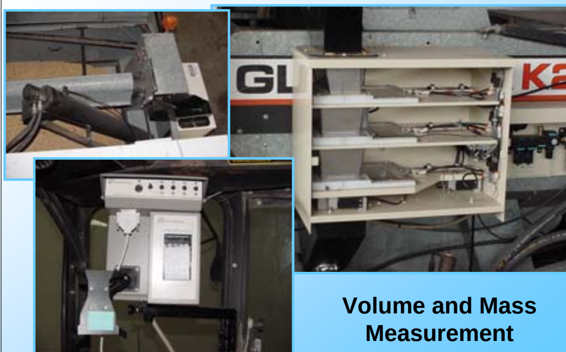


Missotten et al. (1996)

Commercial Grain Flow Sensors



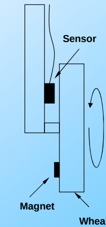
Harvest Master

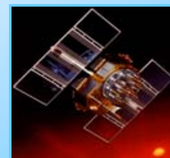


Volume and Mass Measurement

Speed Measurement

- Magnetic Wheel/Shaft Counters
- Speed Sensor
  - Ultrasonic
  - Radar
- Global Positioning System (GPS)





Moisture Compensation

$$Yield_{compensated} = Yield \cdot \frac{100 - Moisture}{100 - Moisture_{reference}}$$

$Moisture_{reference}$ = 15.5% for corn
13% for soybean
12% for sorgum

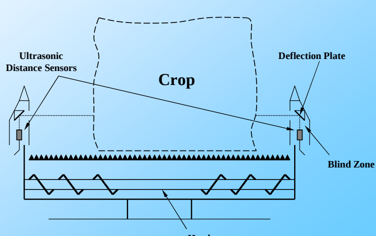
Protein Sensor

A near-infrared (NIR) sensor is used to analyze the light transmitted through a sample of grain. The measurements have been used to determine protein, moisture and oil content. Most experience has been with winter wheat. Sampling rate is adjusted according to the travel speed and is usually 5 samples/min.

http://www.zeltex.com/accuharvest.html

Cutting Width Sensor

- Manual Setting
- GPS Position-Based Method
- Ultrasonic Sensing



Calibration

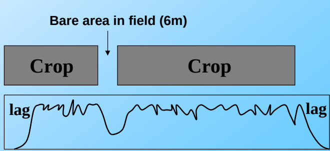
***Calibration** involves the selection of standards and procedures and the determination of calibration coefficients to convert measured signals to desired parameters.*

- Grain Flow Sensor
- Grain Moisture Sensor
- Temperature Sensor
- Speed Sensor

Sources of Error in Yield Monitoring

- Unknown crop width entering the header during harvest
- Time lag of grain through the threshing mechanism
- The inherent 'wandering' error from the GPS
- Surging grain through the combine transport system
- Grain losses from the combine
- Sensor accuracy and calibration

Blackmore and Marshall, 1996



Hole in the Crop Phenomena

Uncertainty Analysis

$$\frac{w_Y}{Y} = \frac{1}{Y}\sqrt{\left(\frac{\partial M}{\partial Y} w_M\right)^2 + \left(\frac{\partial W}{\partial Y} w_W\right)^2 + \left(\frac{\partial V}{\partial Y} w_V\right)^2} = \sqrt{\left(\frac{w_M}{M}\right)^2 + \left(\frac{w_W}{W}\right)^2 + \left(\frac{w_V}{V}\right)^2}$$

Yield Error

Grain Flow Error

Swath Width Error

Travel Speed Error

Assume:

- $w_M/M = 0.05$ (5%)
- $w_W/W = 0.05$ (5%)
- $w_V/V = 0.04$ (4%)

$w_Y/Y = 0.081$ (**8.1 %**)

Basic Text Export Format

Longitude, decimal degrees	Latitude, decimal degrees	Dry Yield, bu/acre	Grain Moisture, %	Monitor Serial Number	Field ID	Load ID	Grain Type
-96.497723	41.164895	78.4	16.2	980415	F33:SITE	L1:END	CORN
-96.497674	41.164893	84.3	16.5	980415	F33:SITE	L1:END	CORN
-96.497628	41.164891	80.5	16.4	980415	F33:SITE	L1:END	CORN
-96.497579	41.164890	70.1	15.9	980415	F33:SITE	L1:END	CORN
-96.497531	41.164889	70.4	15.7	980415	F33:SITE	L1:END	CORN

Advanced Text Export Format

Longitude, decimal degrees	Latitude, decimal degrees	Grain Flow, lbs/s	GPS Time	Logging Interval, s	Distance Traveled, in	Swath Width, in	Grain Moisture, %	Header Status, in	Pass Number	Monitor Serial Number	Field ID	Load ID	Grain Type	GPS Status	PDOP	Altitude, ft
-96.497723	41.164895	13.38	1064830674	2	158	240	16.2	33	1	980415	F33:SITE	L1:END	CORN	7	0	1175.9
-96.497674	41.164893	14.35	1064830676	2	157	240	16.5	33	1	980415	F33:SITE	L1:END	CORN	7	0	1175.5
-96.497628	41.164891	13.60	1064830678	2	156	240	16.4	33	1	980415	F33:SITE	L1:END	CORN	7	0	1175.9
-96.497579	41.164890	12.07	1064830680	2	160	240	15.9	33	1	980415	F33:SITE	L1:END	CORN	7	0	1175.8
-96.497531	41.164889	11.87	1064830682	2	157	240	15.7	33	1	980415	F33:SITE	L1:END	CORN	7	0	1175.8

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