Sensors for Crop Productivity, Yield Maps

Area 2 – **Technologies**

Lesson 4 – **Proximal Sensing**

Sequence ID – **13**

UPM

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DISCLAIMER

A2.L4.T1 Sensors for crop productivity, yield maps

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Interest of Estimating Crop Yield

kg/ha

- **Plant Breeder/variety owner**

  Assess Yield of **new varieties**/cultivars →

ACOR

- **Farmer**

  Measure the effect of different soil conditions or **crop growing practices** on crop Yield

tillage system

seeds

other inputs

- **National agricultural authority**

  Gather data of crop Yields all over the country → (**statistics**, agricultural policy)

Icons from:
VectorStock.com
pngtree

Level of complexity in grain yield measuring:

Basic

(on-the-ground weighbridge)

urbinavinos.com

(picture is of a wine-making facility, i.e. grapes)

medium.com

(ground-flush weighbridge)

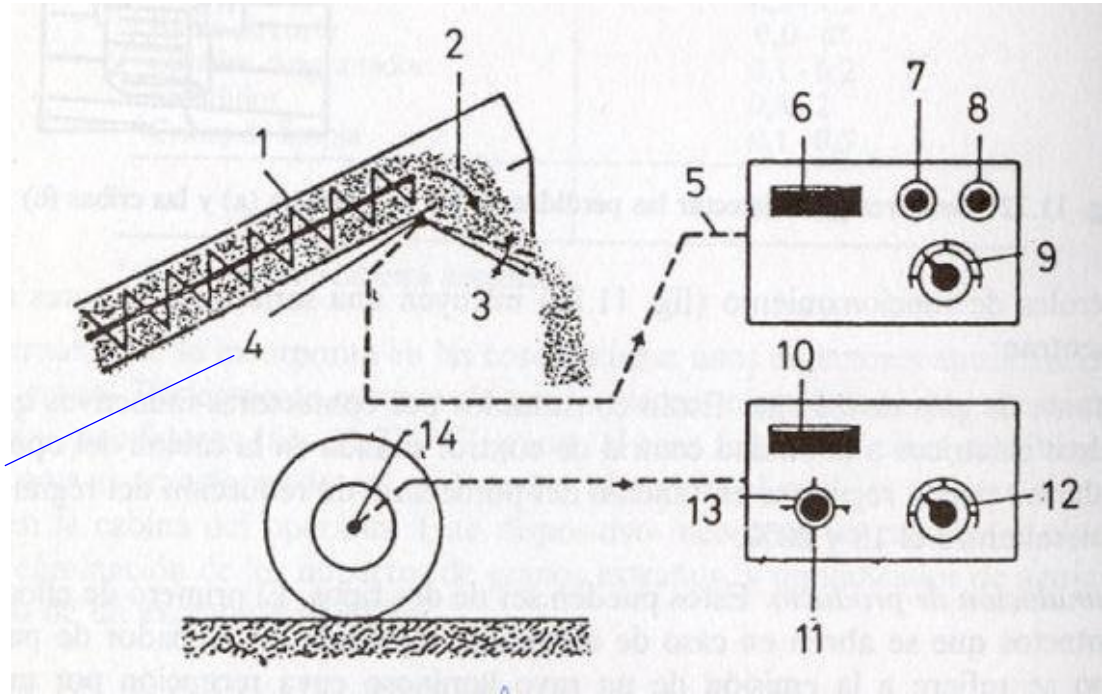
Weighbridge
(a.k.a. truck scale)

Drawbacks:

- Just one single average yield value for the whole field/plot
- Typically, the last trailer (Eur./Spain) loaded with the plot grain will be only partially full

Level of complexity in grain yield measuring: *Intermediate*

Continuous weighing (kg/s) & m^2 harvested/s → kg/ha



4: Strain gauge (load sensor)

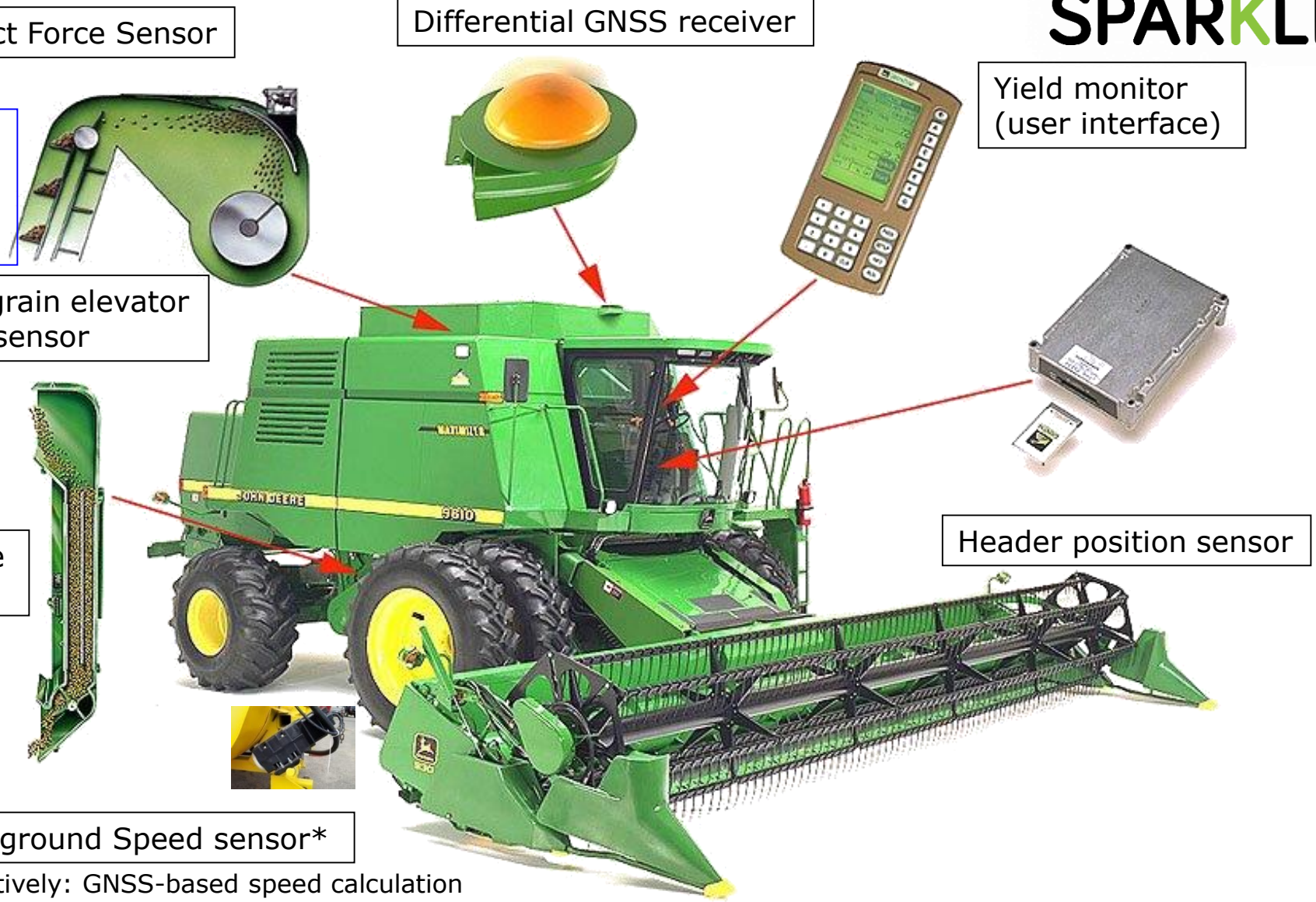
14: Ground speed sensor

Source: Ortiz-Cañavate, J. Técnica de la Mecanización Agraria

- Every time the combine hopper is dumped, the cumulated kg up until then is recorded
- Advantage over weighbridge method: plot yield measuring is on-the-go → multiple values of kg/ha
- Shortcoming: no GNSS ⇒ no yield map

Level of complexity in grain yield measuring: *Advanced*

HW components for Yield Mapping (Geo-referenced)



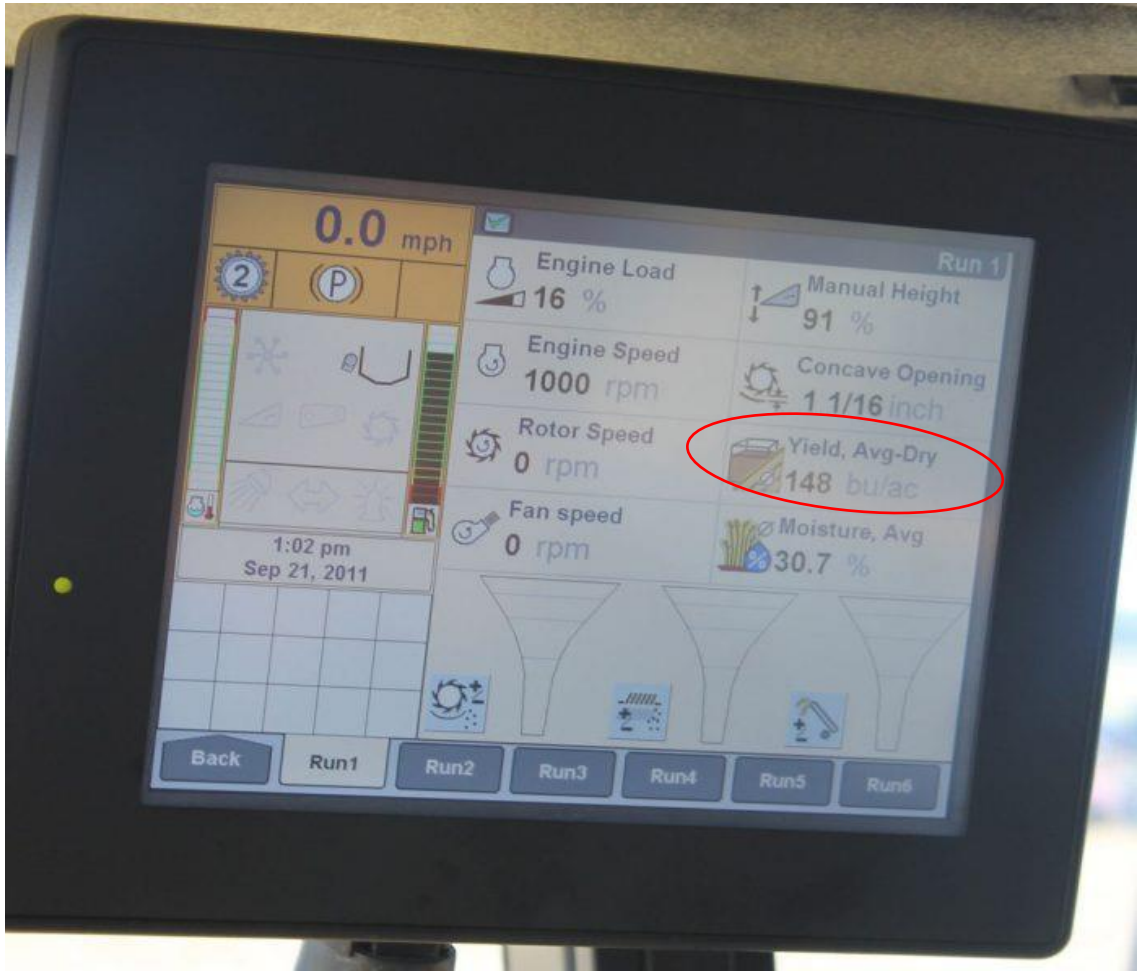
Combine Harvester Yield Monitor (1/2)

Mass Flow (t/h), wet ⇒ “raw” or uncorrected value

Combine Harvester Yield Monitor (2/2)

average **Yield** (bu/ac), '**dry**'

reference or desired moisture content (MC)



Colin W. Wrigley:

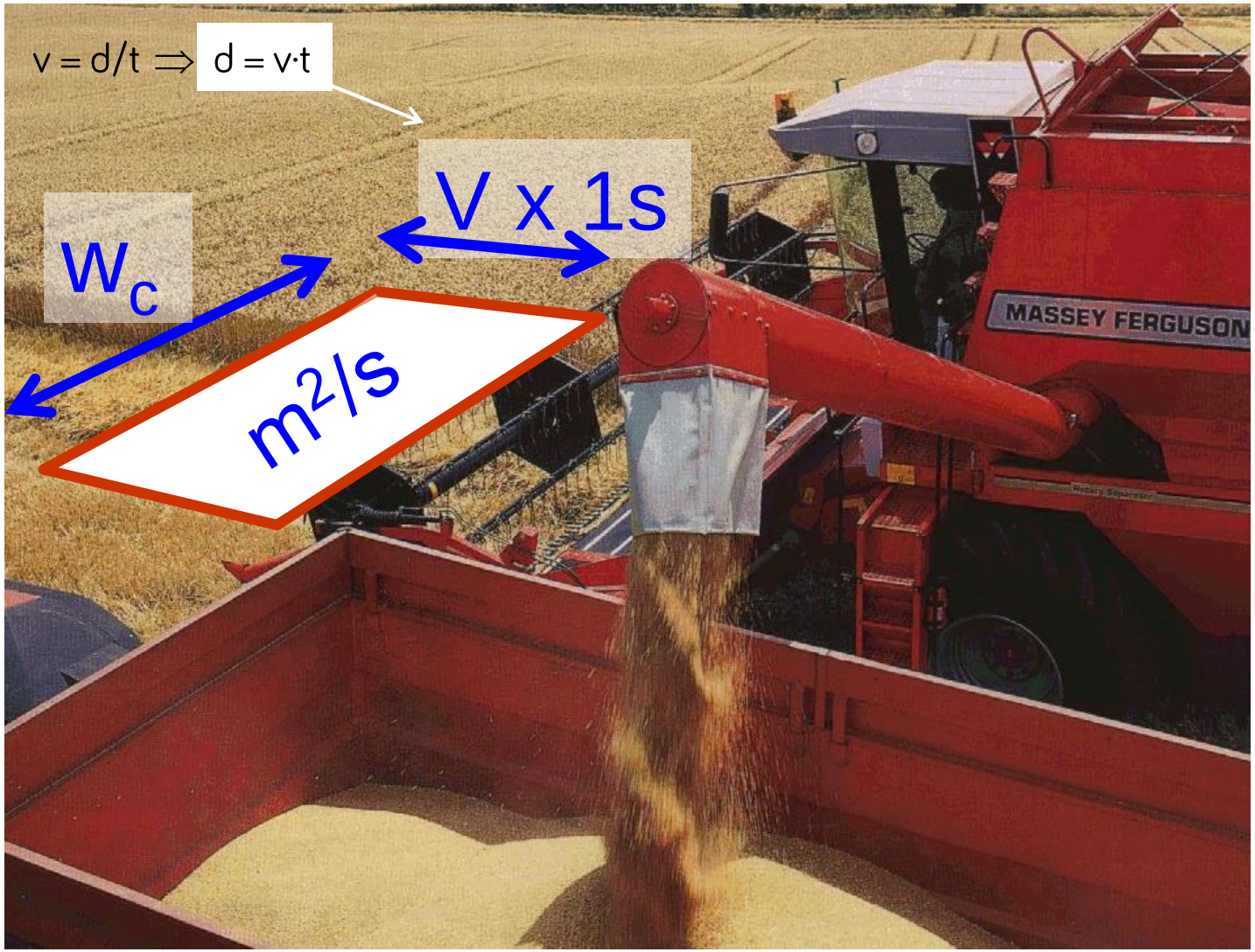
A bushel is primarily an American measure of volume, but it has also become a measure of mass (weight); however, its weight differs for each of several grain species

1 bu (wheat) = 60 lb
1 bu (corn) = 56 lb

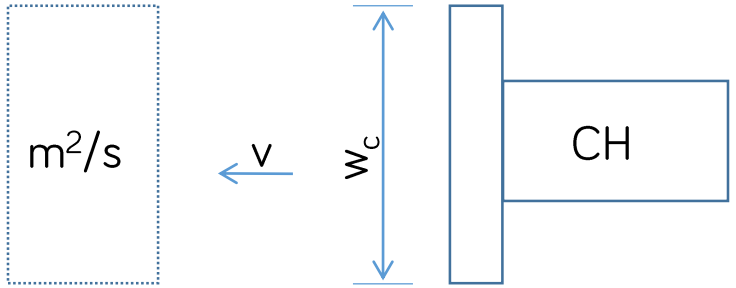
1 ac = 0.4047 ha

Wheat, rule of thumb: lb/ac $\xrightarrow{\times 1.1}$ kg/ha $\longrightarrow$ Wrigley, C.W. (2010). Equivalence between metric and U.S. units for the grain industry. Cereal Foods World, 55(1): 32-34

Yield Computation (1/3)



Yield Computation (2/3)



mass flow (**kg/s**)
impact sensor

clean-grain elevator

$$\text{Yield (wet)} = \frac{\text{kg/s}}{\text{m}^2/\text{s}} = \frac{\textbf{kg}}{\textbf{m}^2}$$

(grain with its actual-field-$\textbf{MC}_{\textbf{harvest}}$)

lag-time or delay: 5-20 s: **average *time*** elapsed between the instant when a crop plant is mown and the instant when its grains impact against the mass flow sensor. This lag is taken into account for **yield map** construction.

Yield Computation (3/3)

Moisture Content (MC) correction

- Moisture Sensor (**MS**): only a fraction (sample) of the grain flow is presented to this sensor
- Complemented with a temperature sensor

$$\mathbf{Y}\ (\text{'dry'}) = \mathbf{Y}\ (\text{wet}) \cdot \frac{\mathbf{100\text{-}MC_{harvest}}}{\mathbf{100\text{-}MC_{reference}}}$$

Example:

$MC_{harvest} = 18\%$

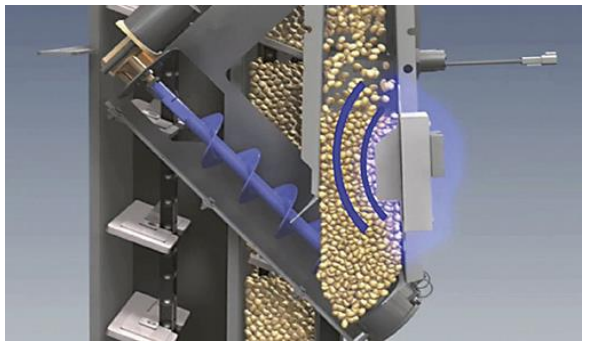
$MC_{ref.} = 13\%$

$100\text{-}MC_{harvest} = 82$

$100\text{-}MC_{ref.} = 87$

$$\frac{82}{87} \cong 0.94\ (< 1)$$

- Apart from yield mapping, **MS** readings are valuable for CH optimum adjustment (thresher concave-cylinder clearance)



New Holland's MS measures **grain moisture** in real time. Samples are taken every 30 s and the data is sent to the monitor

MS requires periodic calibration (e.g. against accurate hand-held grain MS)

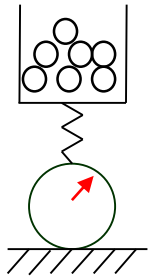
- If the **MS** overestimates grain MC, **Y** will be underestimated

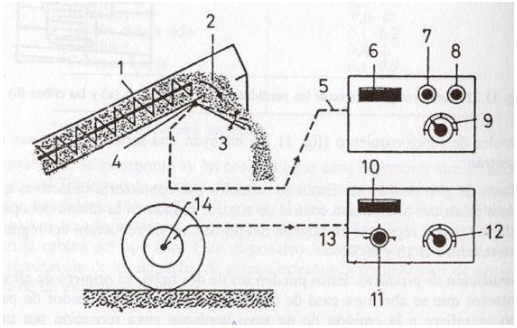
Example (continued): Let the MS reading be 20% (while true or actual is 18%):
$100\text{-}MC_{harvest} = 80$; $80/87 = 0.92$ (<0.94)

Types of yield sensors

Mass Flow

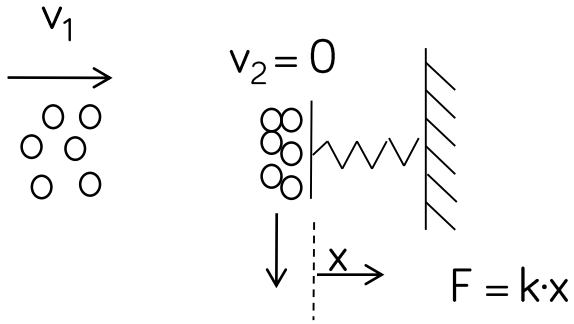
- **Gravimetric** (m·g)





→ kg/s

- **Momentum** (m·v) **variation**
  (a.k.a. **impact force** yield sensor)

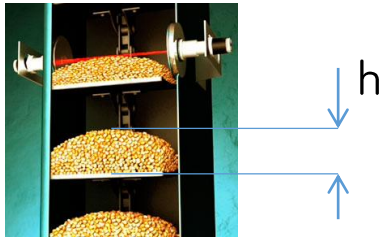


Clean-grain elevator

→ kg/s

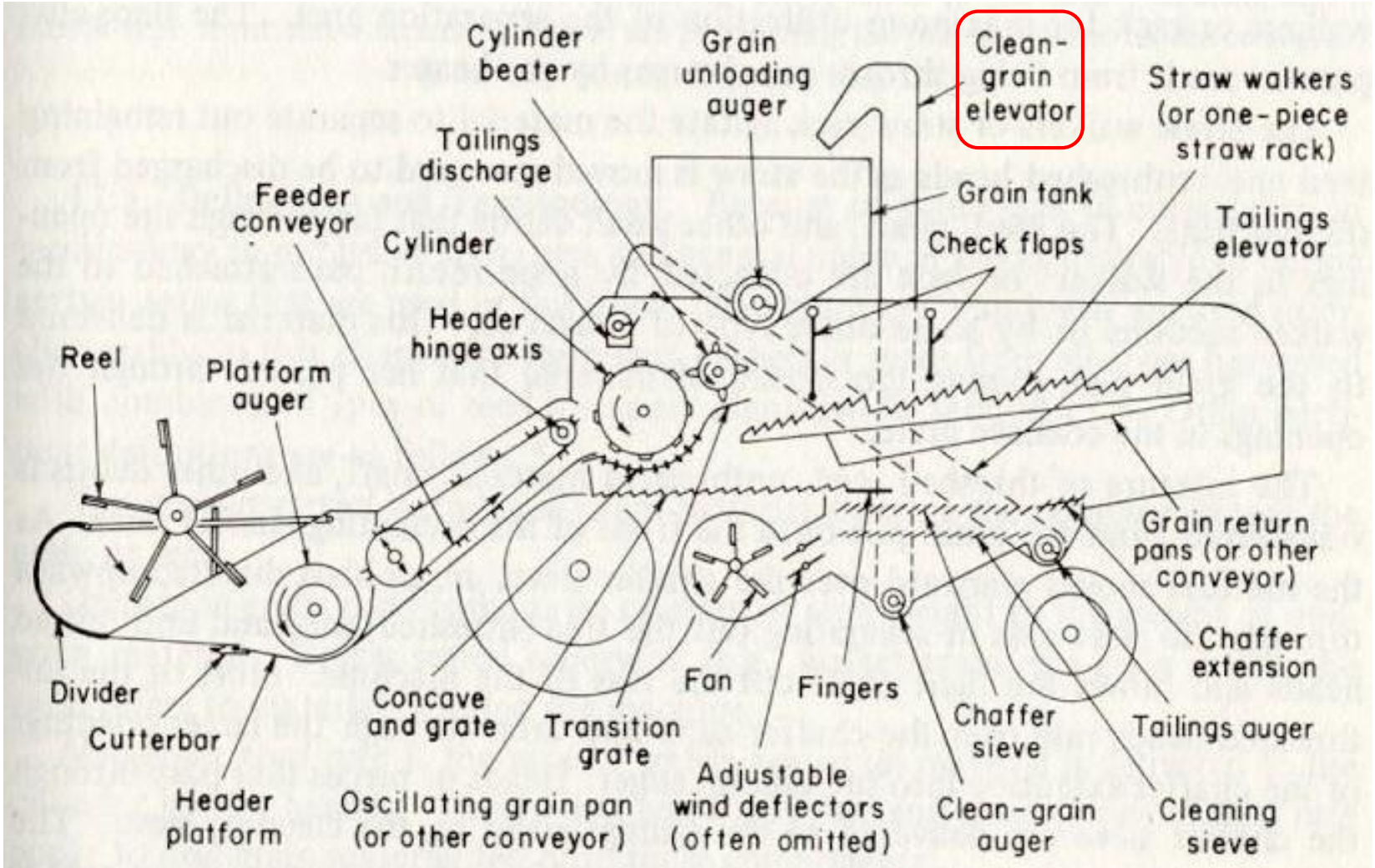
- **Volumetric** (from *h*)

V= a·b·h



→ L/s

Location of the *clean-grain elevator* in the CH

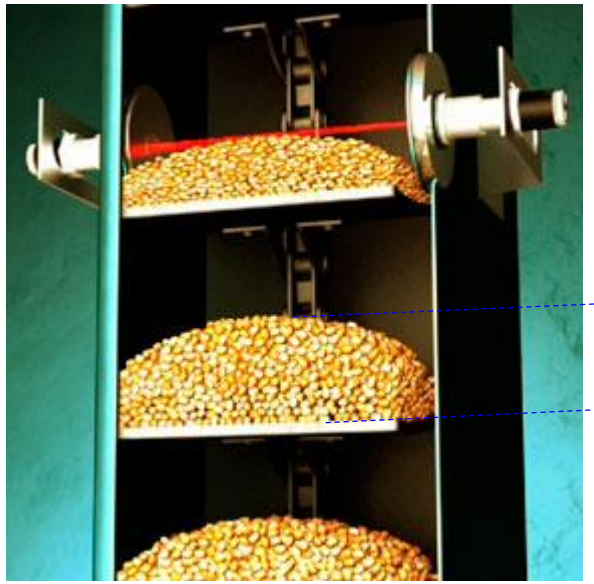


Kepner et al. Principles of Farm Machinery

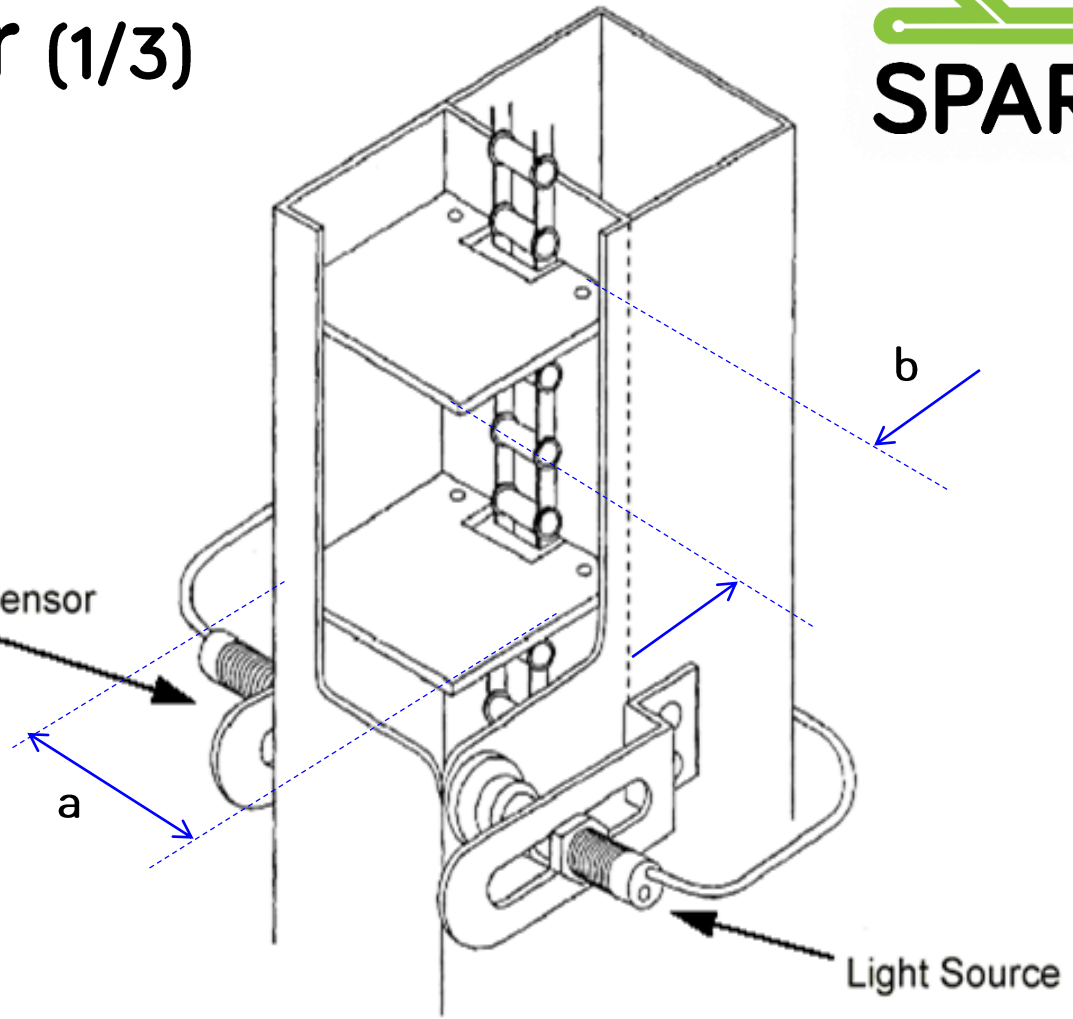
Volumetric yield sensor (1/3)

Optical

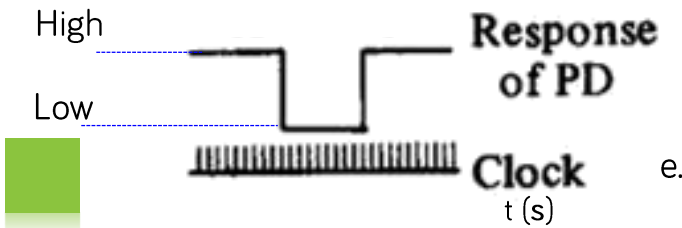
clean-grain elevator



$\uparrow h \Rightarrow \uparrow t_{\text{light blocked}}$



Digital state



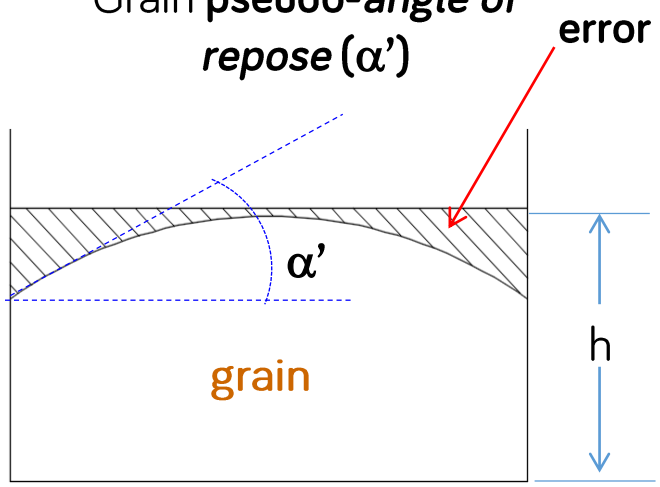
e.g.:
- High → Light detected
- Low → Light blocked (grain)

Result: **L/s** (finally converted to kg/s by means of estimating a *test weight* (apparent specific weight)

Volumetric yield sensor (2/3)

Optical, Sources of Error

Grain **pseudo-*angle of repose*** (α')

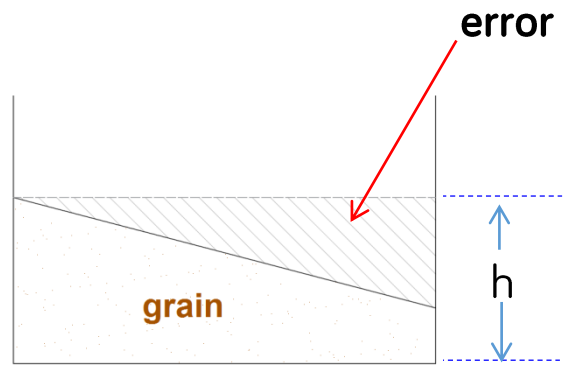


$V \neq a \cdot b \cdot h$

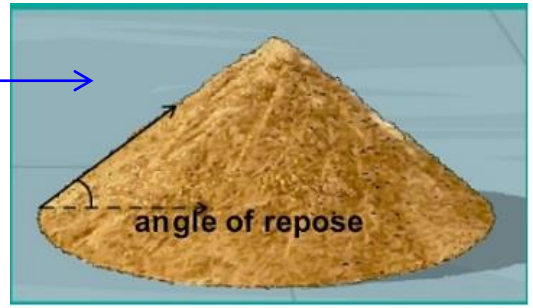
(α' can be *a priori* estimated)

'pseudo' is to differentiate the 'bucket' elevator case –constraining lateral walls- from:

Combine harvester inclination due to **terrain slope**



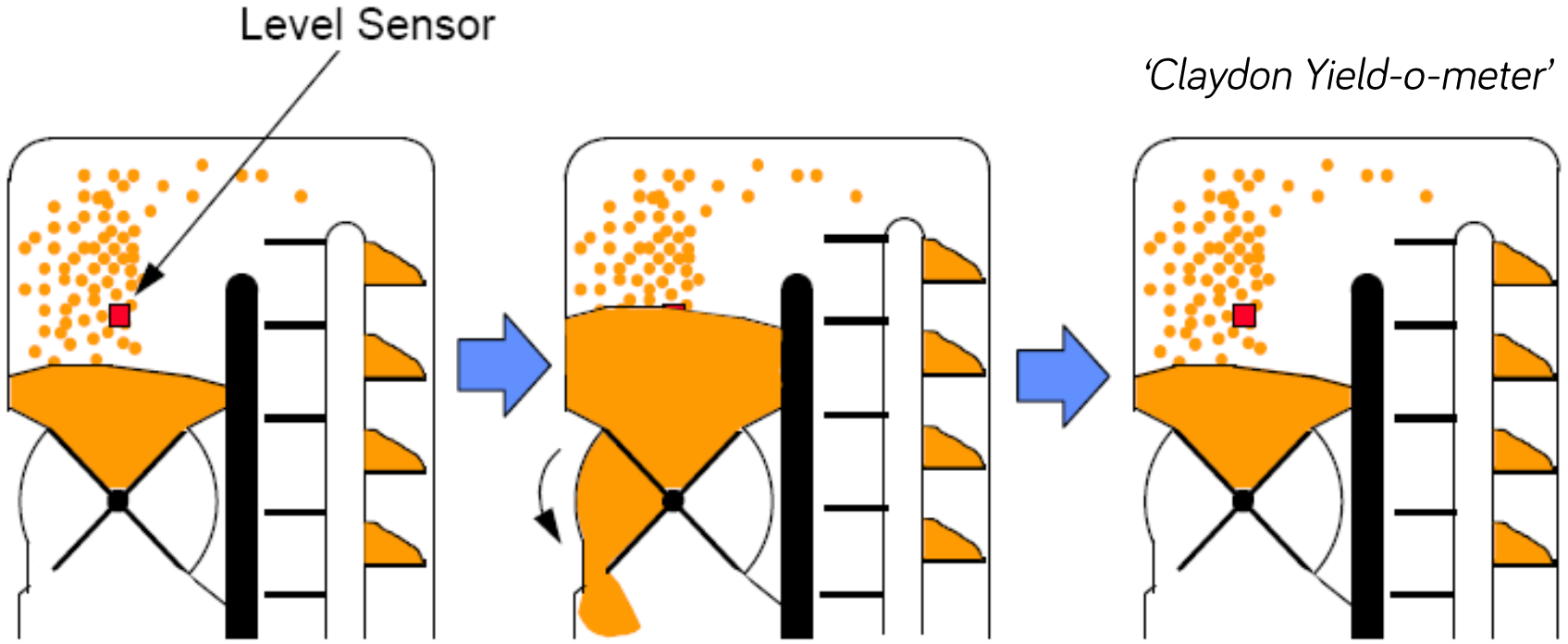
True angle of repose = α



http://bulkcarrierguide.com/carriage-of-grain.html

Volumetric yield sensor (3/3)

Optical & Mechanical



'Claydon Yield-o-meter'

Paddle wheel (4 pockets) installed at point of discharge of the clean-grain elev.

Input data
- V_{pocket} (L)
- Number of discharges/s
- ρ_{grain} → to convert L/s → kg/s

Swath width

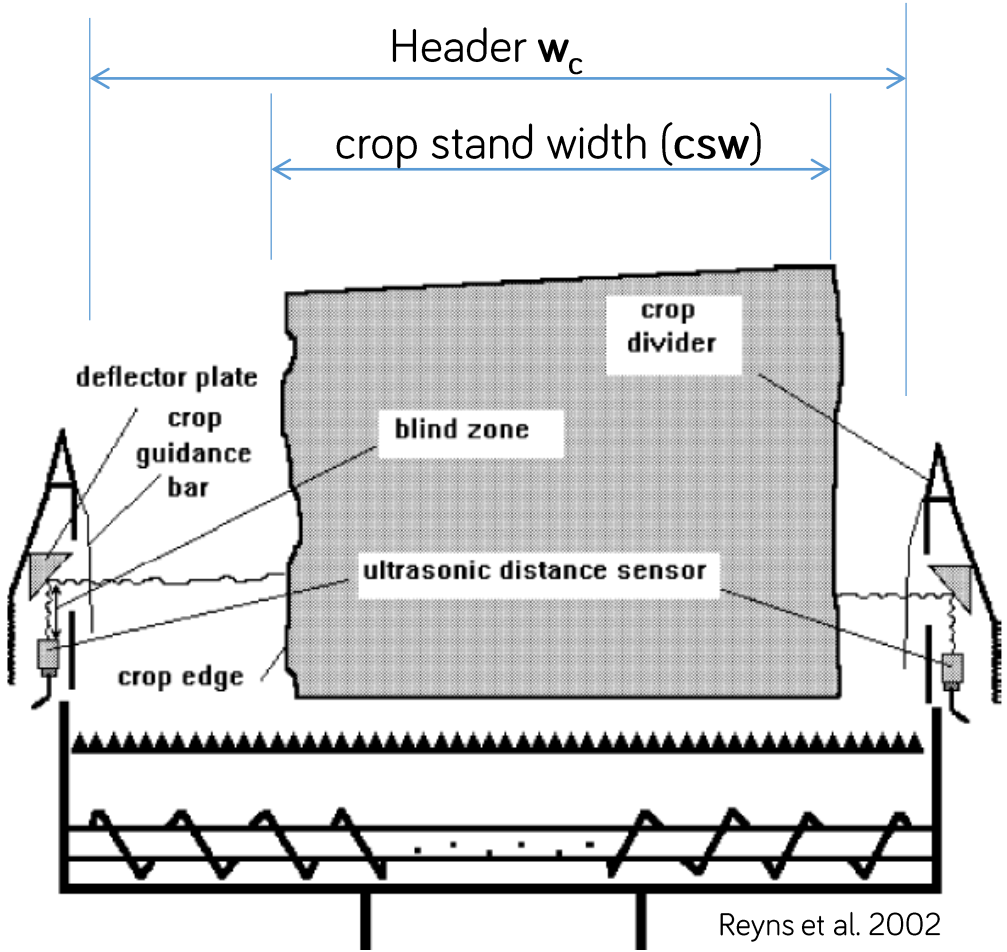
Most Y monitors allow the operator to indicate (Y monitor's touch-screen) whether the combine harvester is operating at a 100% w_c or less ('eye' estimation in the latter case…)

Technical advance: Measurement of w_c by aid of **US** sensors

easier for corn: count the number of rows instead of estimating a % of the header cut width w_c

depicted case:

csw < w_c



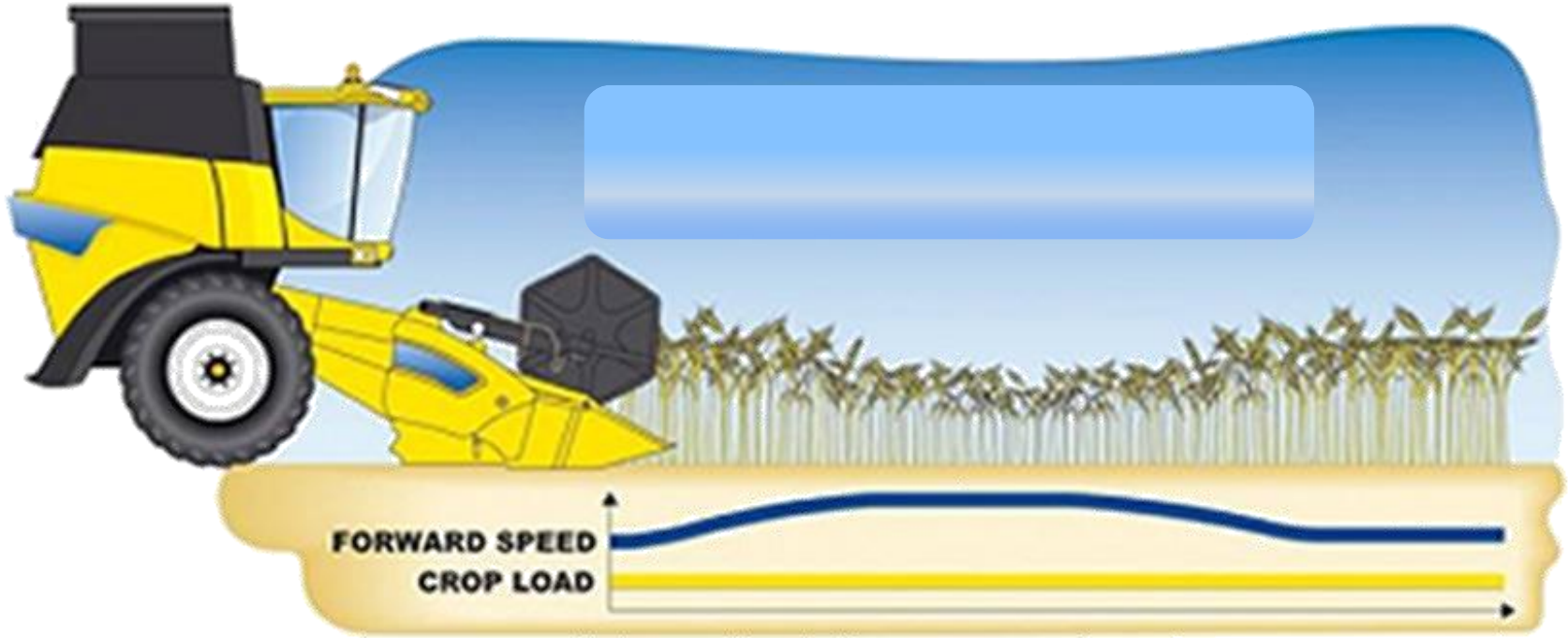
Reyns et al. 2002

(If the system is not informed that the trip is not a full-width one, Y will be underestimated)

Combine harvester Forward ground Speed

‘Conflict of interest’

Constant crop load: Combine’s automatic control which **adjust fwd. ground *v*** to maintain a constant machine load (grain intake rate)



For the sake of yield map accuracy, constant ground speed is recommended

If main interest is obtaining a yield map, *constant crop load* function should be disengaged

Yield sensor calibration (1/2)

- **Due: Often**
  - **Conventional, manual (batch calibration)**
    - time-consuming
    - calibration process:

      1st: Harvest a small (e.g. 1500 kg) load of grain

      2nd: Drive to the *Weighbridge* to measure the *truck scale* weight

Calibration factor

$$C = C_{std.} \cdot \frac{(m \cdot g)_{monitor}}{(m \cdot g)_{truck\ scale}}$$

$C_{std.}$ = default calibration factor for the grain type considered

Typ.: 2-6 loads/calibration

(points in the calibration curve)

  - Continuous, automated

    (e.g., JD's *ActiveYield*)

    - Provides **continuous** calibration of the mass flow sensor through **load cells installed in the grain tank**
    - Load Cells in the grain tank estimate the change in **weight** of grain, as the grain tank fills

Yield sensor calibration (2/2)

Parker Farm Equipment

SPARKLE

grain cart:
more in USA than in Eur./Spain

What is an ActiveYield Load?

It is not a full grain tank and it is not a full truck/grain cart load.

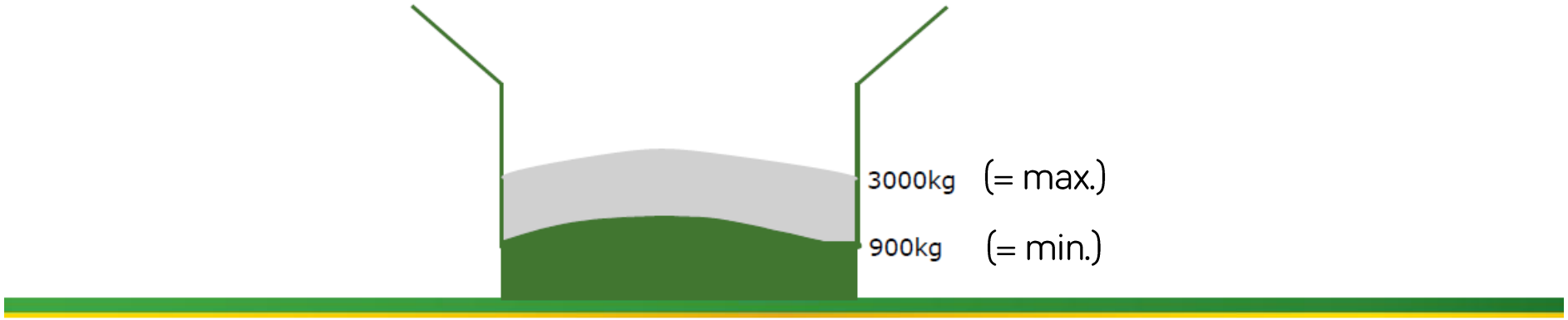
The system starts taking data when the load cells indicate that grain is accumulating in the grain tank @900kg.(2000lb.) (min.)

ActiveYield **stops** accepting measurements when the load cells indicate the grain weight @ 3000kg.(6600lb.) (max.)

Load will be saved as long as:

- Harvested crop is uniform to support constant flow during load collection
- Field terrain (roll and pitch) are within +/-4°
- No interruptions with grain flow during load collection (stopping-starting, unloading, grain pile shift, disengaging separator).

commutes between CH & field edge where the semi-trailer truck waits...



JOHN DEERE

Protein sensor

"On-the-go combine **protein sensors** increase wheat margins"

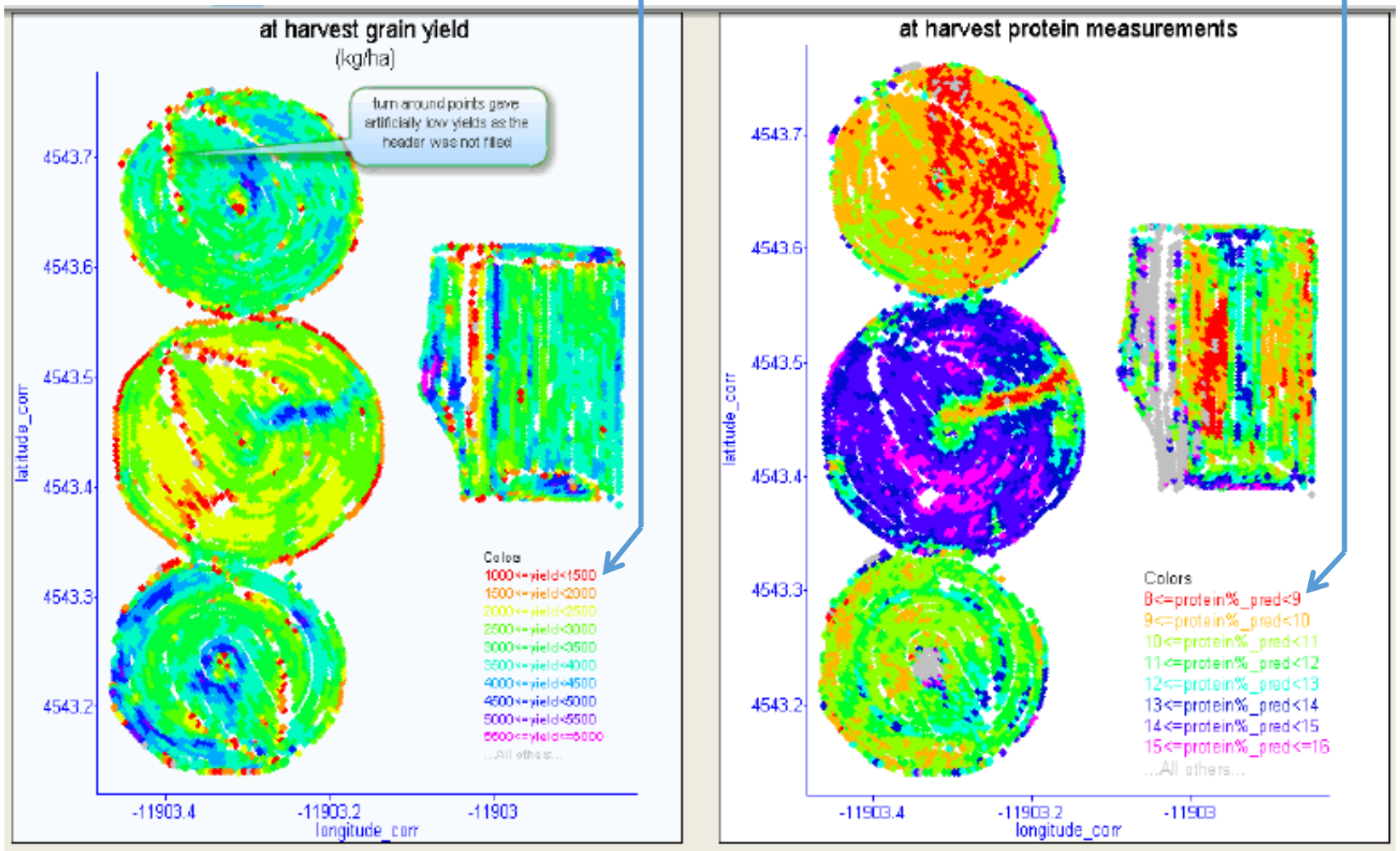
Protein sensor mounted on the clean grain elevator

https://www.futurefarming.com/Machinery/Articles/2017/9/On-the-go-combine-protein-sensors-increase-wheat-margins-2902WP/

Yield & Protein Maps (1/2)

Red: yield between (btw.) 1000 and 1500 kg/ha

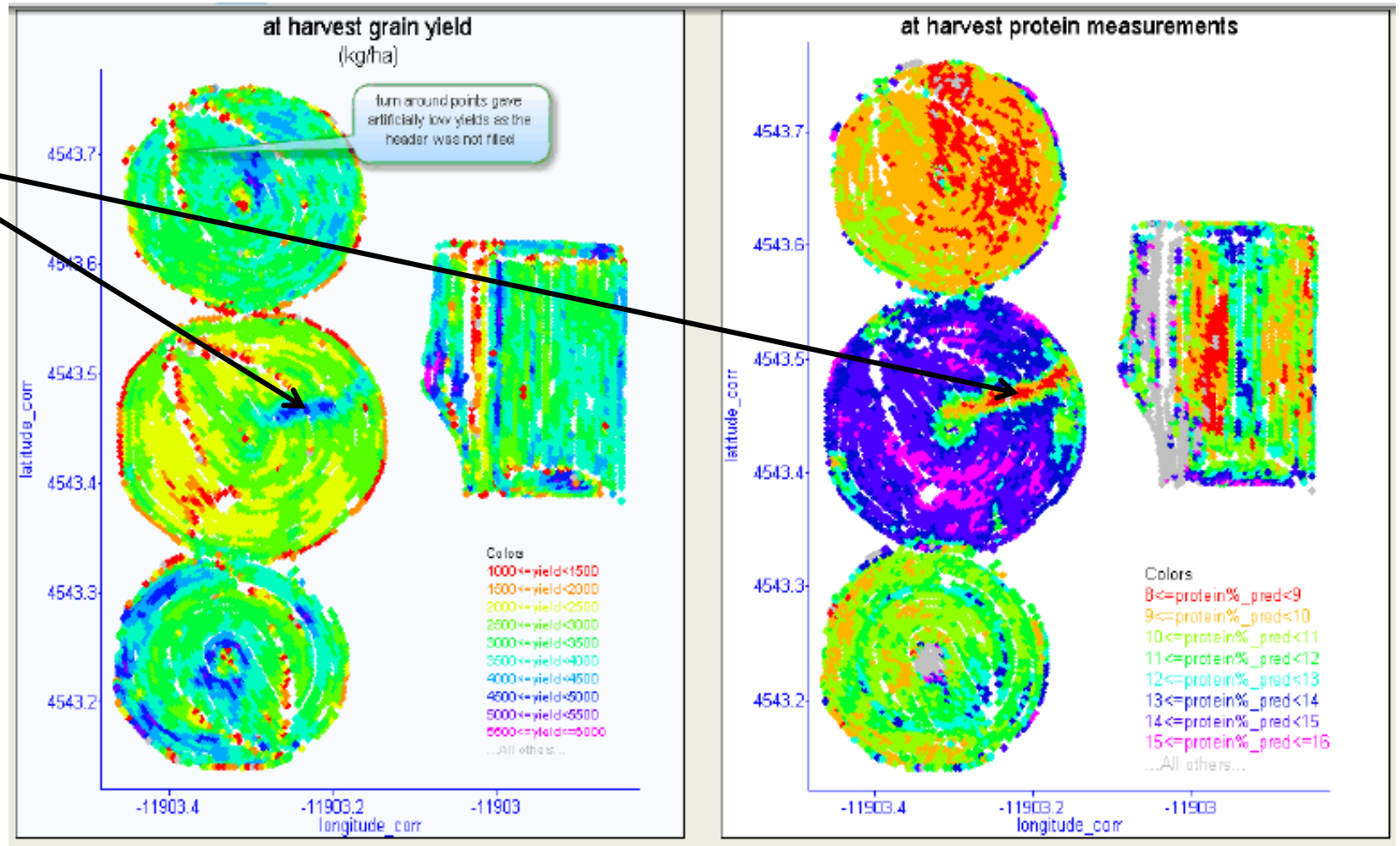
Red: **% protein** btw. 8 and 9
Pink: **% protein** btw. 15 and 16



Source: USDA-ARS

Yield & Protein Maps (2/2)

Spot of ↑ **kg/ha**
and ↓ **% protein**



Source: USDA-ARS