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DEVELOPMENT OF A TRAINING PROGRAM FOR ENHANCING THE USE OF ICT TOOLS IN THE IMPLEMENTATION OF PRECISION AGRICULTURE

Sensors and Electronics

Proximal Sensing

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Introduction to Proximal Sensing

- Proximal Sensing refers to any measurement that is taken at **ground level**, inside the field.
- There are several sensors used to collect different types of proximal data, varying from simple scaling instruments to sophisticated autonomous systems.

Soil Electrical Conductivity

- One of the most basic applications of proximal data is the sensing of soil properties.
- Soil attributes are strongly connected with each other. For example, soil structure can give us an estimation on evapotranspiration and therefore water availability on the root system throughout the growing period.

Soil Electrical Conductivity

- Electrical conductivity (EC) is a fundamental property of materials that characterizes the ability of a mean to conduct or resist electricity (dS/m).
- “Electrical Conductivity quantifies how strongly a material resists or conducts electric current”

Soil Electrical Conductivity

- In agriculture, soil EC is the most widely used parameter for management zone delineation, because it demonstrates high temporal stability.

Management Zone Delineation → **The fundamental pillar of P.A.** → **Different Management in each Zone**

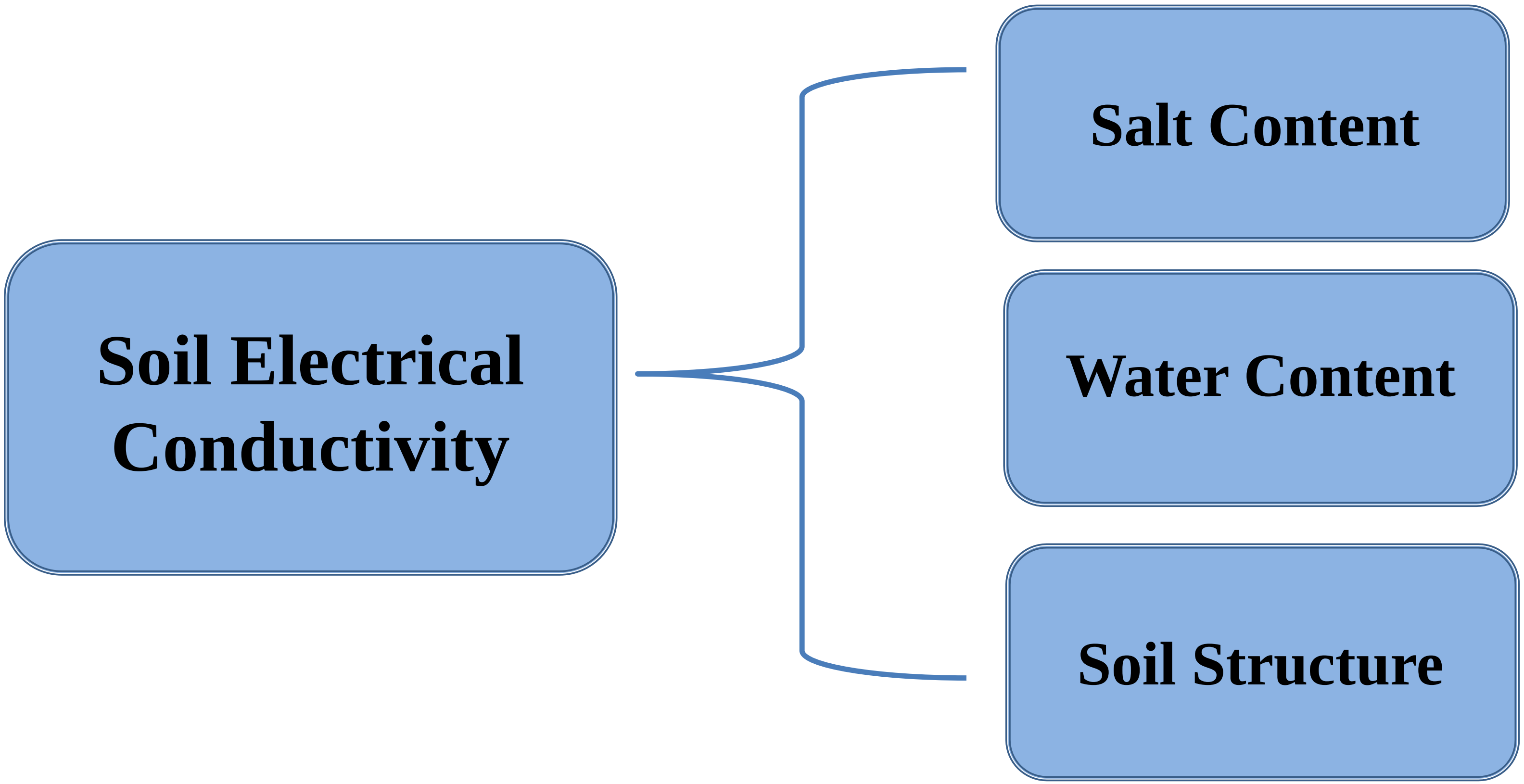
Soil Electrical Conductivity

- Soil EC is related to several soil physical and chemical properties.
- EC data can be translated to a large number of agronomical insights of great value, with relatively high accuracy.

Soil Electrical Conductivity

- Soil EC increases at soils with higher salt concentration.
- At the same time, salt concentration (%) depends on water content and therefore Soil Moisture

Soil Parameters related to EC



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Soil Parameters related to EC

Soil attributes are related to each other. Knowing one of them can provide estimations about a large number of other parameters:

- Salt concentration
- Porosity
- Temperature (Thermal)
- Structure
- Organic Matter
- pH
- Cation Exchange Capacity
- Water Content

Soil EC Sensors

- EC is commonly expressed in units of milliSiemens per meter (mS/m), or deciSiemens per meter (dS/m), which is 100 times greater than milliSiemens per meter.

- Soil EC sensors are divided into two main categories:
  - Contact Sensors
  - Non-contact Sensors

Non-Contact Soil EC Sensors

- Non-contact soil EC sensors do not require direct contact with the soil to work, since they use the principle of electromagnetic induction to collect data.
- The electromagnetic induction method is based on the measurement of the change in mutual impedance between a pair of coils close to the soil's surface.

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Non-Contact Soil EC Sensors

- Most non-contact EC sensors consist of a single transmitter coil and two receiver coils.
- All coils are electrically connected and are separated by a fixed distance, to enable measurements at different depths.
- Non-contact soil EC sensors typically enable measurements at greater soil depth than contact sensors.

Non-Contact Soil EC Sensors

- The transmitter coil is used to generate an electromagnetic field, called primary field, which causes electrical currents to flow in the soil subsurface.
- The flow of currents in the subsurface generate a secondary magnetic field. Both the induced secondary field and the primary field are detected at the receiver coil, and soil EC is calculated.

Non-Contact Soil EC Sensors

- Geonics is a Canadian manufacturer of non-contact soil EC sensors, the EM38 system.
  - System with 2 receiver coils, separated by 1 m and 0.5 m from the transmitter
  - Offers 2 effective depth ranges

Source: geomatrix.co.uk

Non-Contact Soil EC Sensors

- The EM38 MK2 sensor can measure at 1.5 m and 0.75 m depth respectively when positioned vertically, and 0.75 m and 0.375 m when in horizontal orientation.

The Archer logger of the EM38 MK2 sensor, used to control the sensors operations and data collection

Non-Contact Soil EC Sensors

- The sensor has no GPS inside it, and therefore requires an GPS device to log spatial data.
- The logger / controller of the instrument can be used as a GPS, however, other high accuracy GPS such as an RTK GPS can be connected to enable higher positioning accuracy for each measurement.

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Non-Contact Soil EC Sensors

- Once the sensor is connected with a GPS via the logger, it can be used to collect EC data manually, or can be placed on a sledge pulled by an agricultural vehicle for large fields.

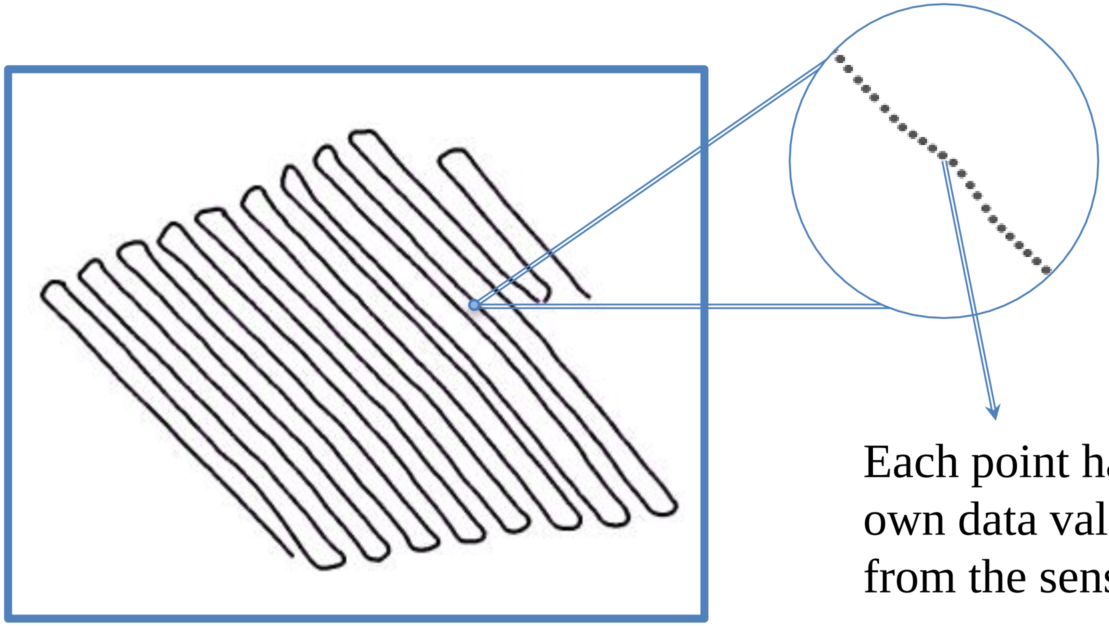
Wooden sledge with the sensor and GPS placed in it, **without** any metallic objects

Non-Contact Soil EC Sensors

- Once the georeferenced data points have been collected, data can be processed and analyzed in a GIS software.
- The approach is to **interpolate** a constant surface from the points' values.
- The methodology presented here is **similar to all georeferenced data** from proximal sensors.

Proximal Sensor Data

- Once the sensor has scanned the entire field, georeferenced data has been collected in the form of points, as it appears below.

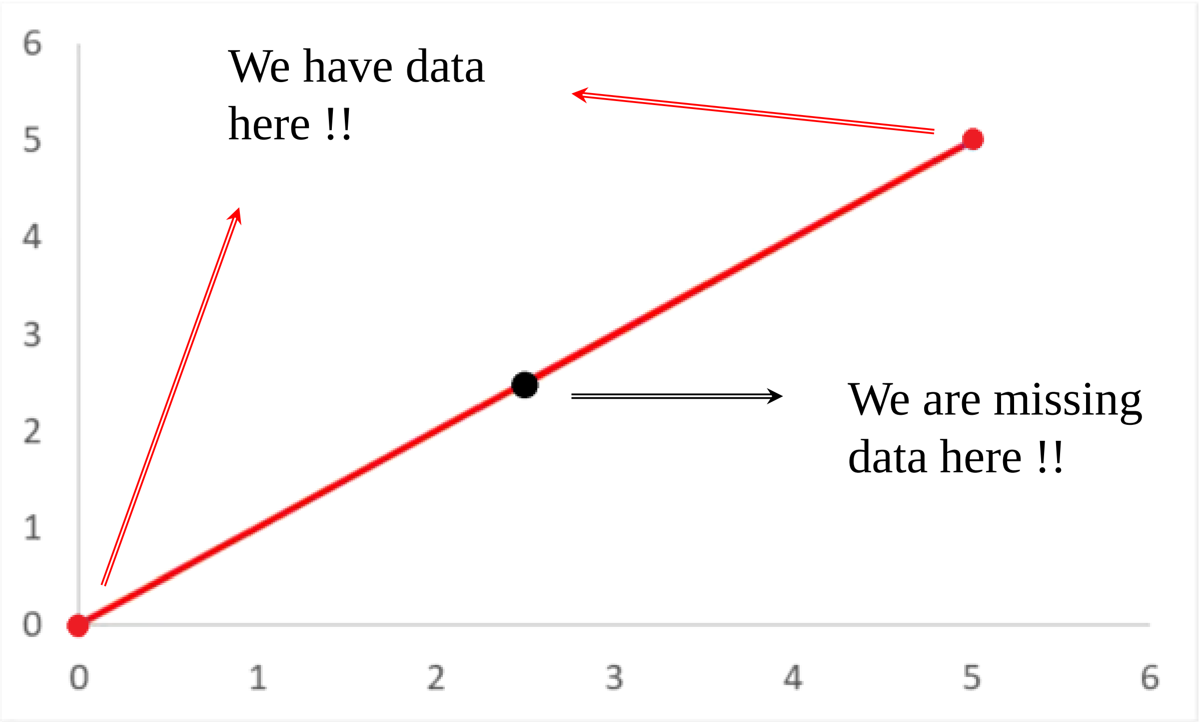


Each point has its own data values from the sensor

Data interpolation - IDW

- Most proximal sensors generate point Vector files, with each of them having a value of the measured parameter.
- Data must be converted from point (vector) to a continuous surface (raster).
- We must "generate", or **estimate** data for the points were no measurements have been taken.

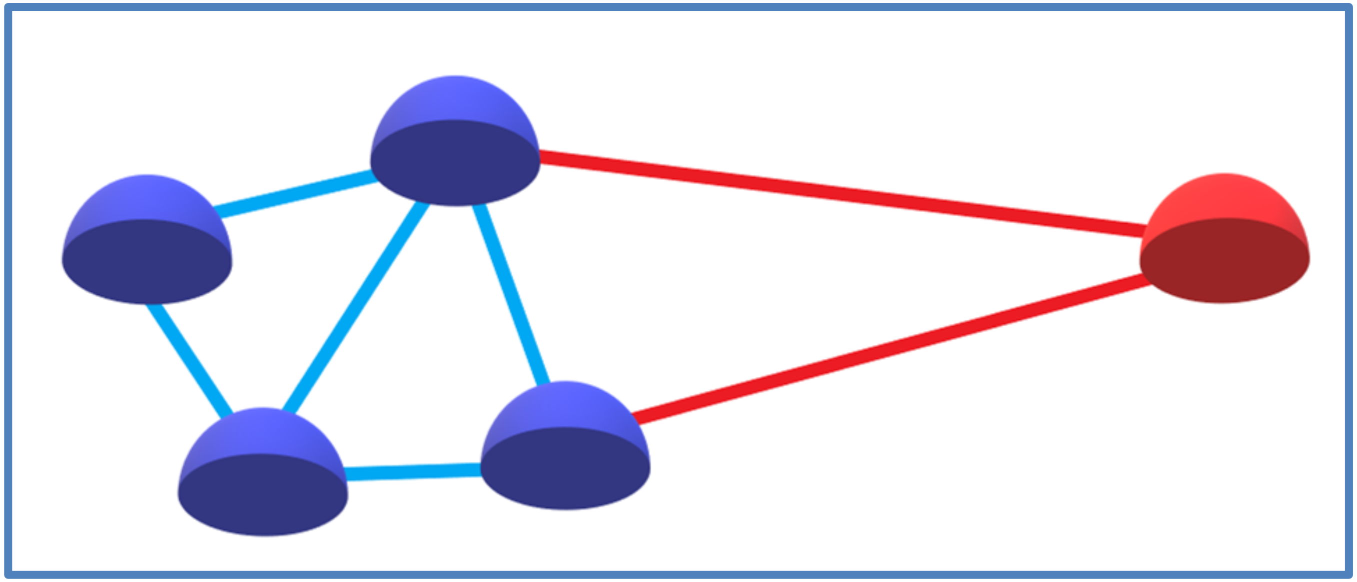
Data interpolation - IDW



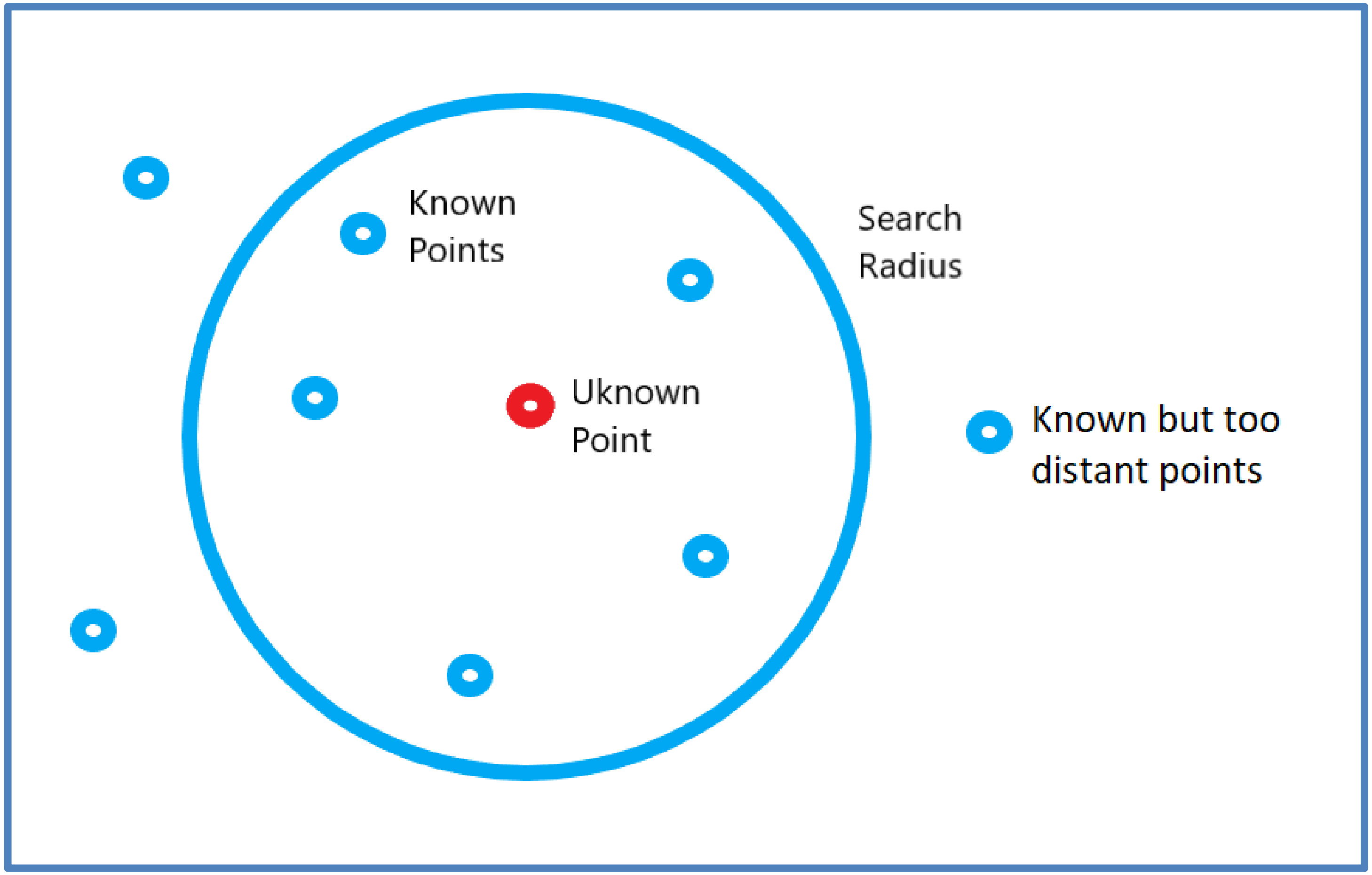
Data interpolation - IDW

Everything is related to all, but those which are near are more related.

-Waldo Tobler, 1970



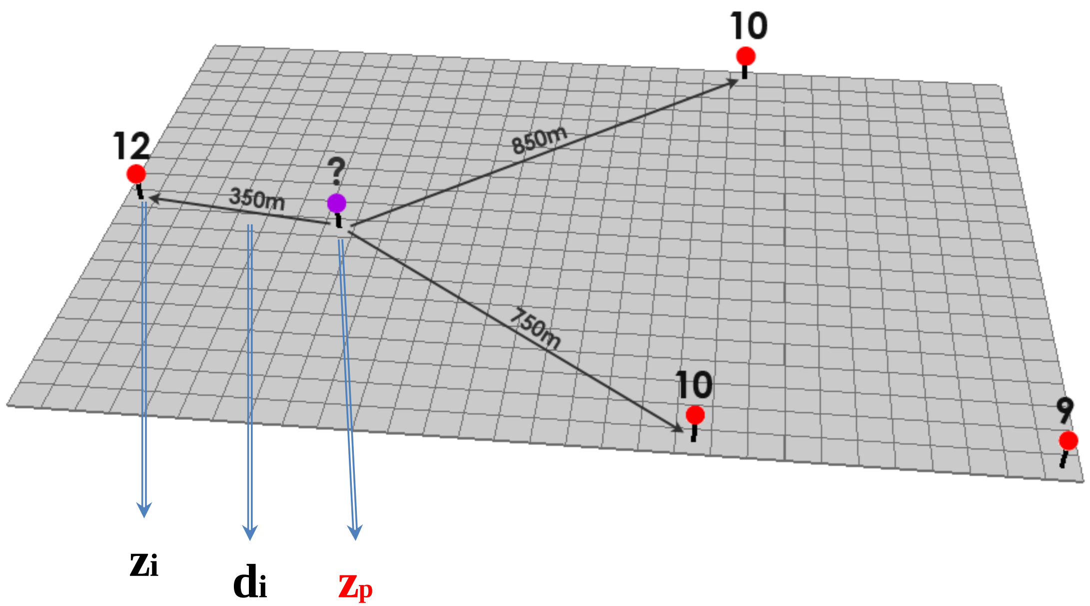
Data interpolation - IDW



Inverse Distance Weighting

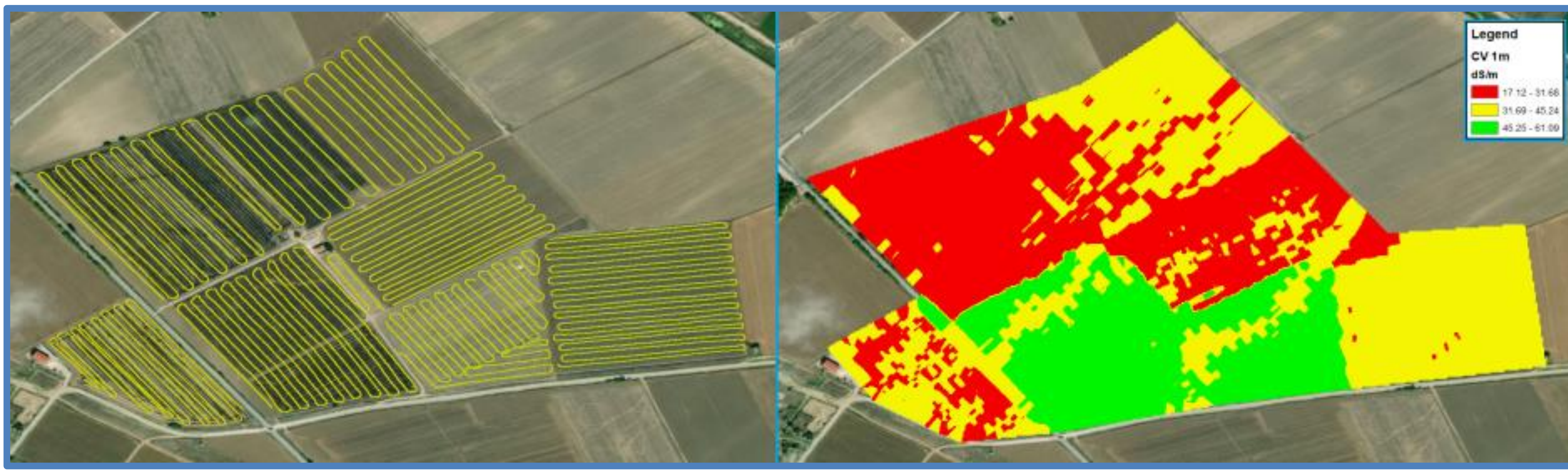
➢ Simple Spatial Interpolation example

$$z_p = \frac{\sum_{i=1}^{n} \left(\frac{z_i}{d_i^p} \right)}{\sum_{i=1}^{n} \left(\frac{1}{d_i^p} \right)}$$



Data interpolation - IDW

- The result of the spatial data interpolation process is a map that demonstrates the spatial variability of the measured parameter.



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Soil EC Contact Sensors

- Contact sensors use the method of generating electrical current from a transmitter electrode and then measuring the voltage drop with one or two receiver coils.
- Both coil types are in contact with the ground / soil upper layer, thus the name "contact sensors".

Soil EC Contact Sensors

- Veris Technology is a manufacture of contact electrical conductivity sensors.
- In Veris systems two to three pairs of electrodes are used. One pair of transmitters creates electrical current to the soil while the remaining receivers measure the voltage drop between them and calculate soil EC.

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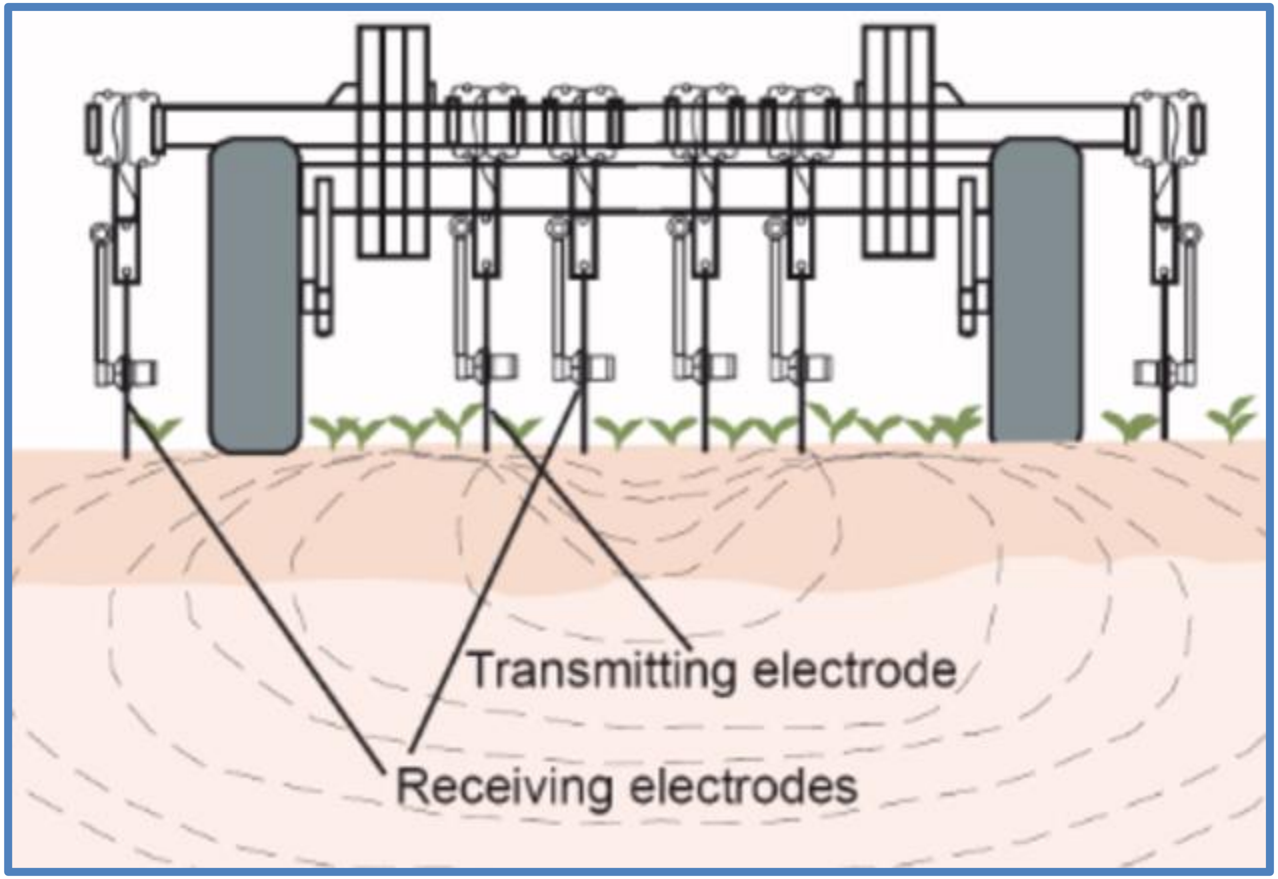
Soil EC Contact Sensors

Source: veristech.com

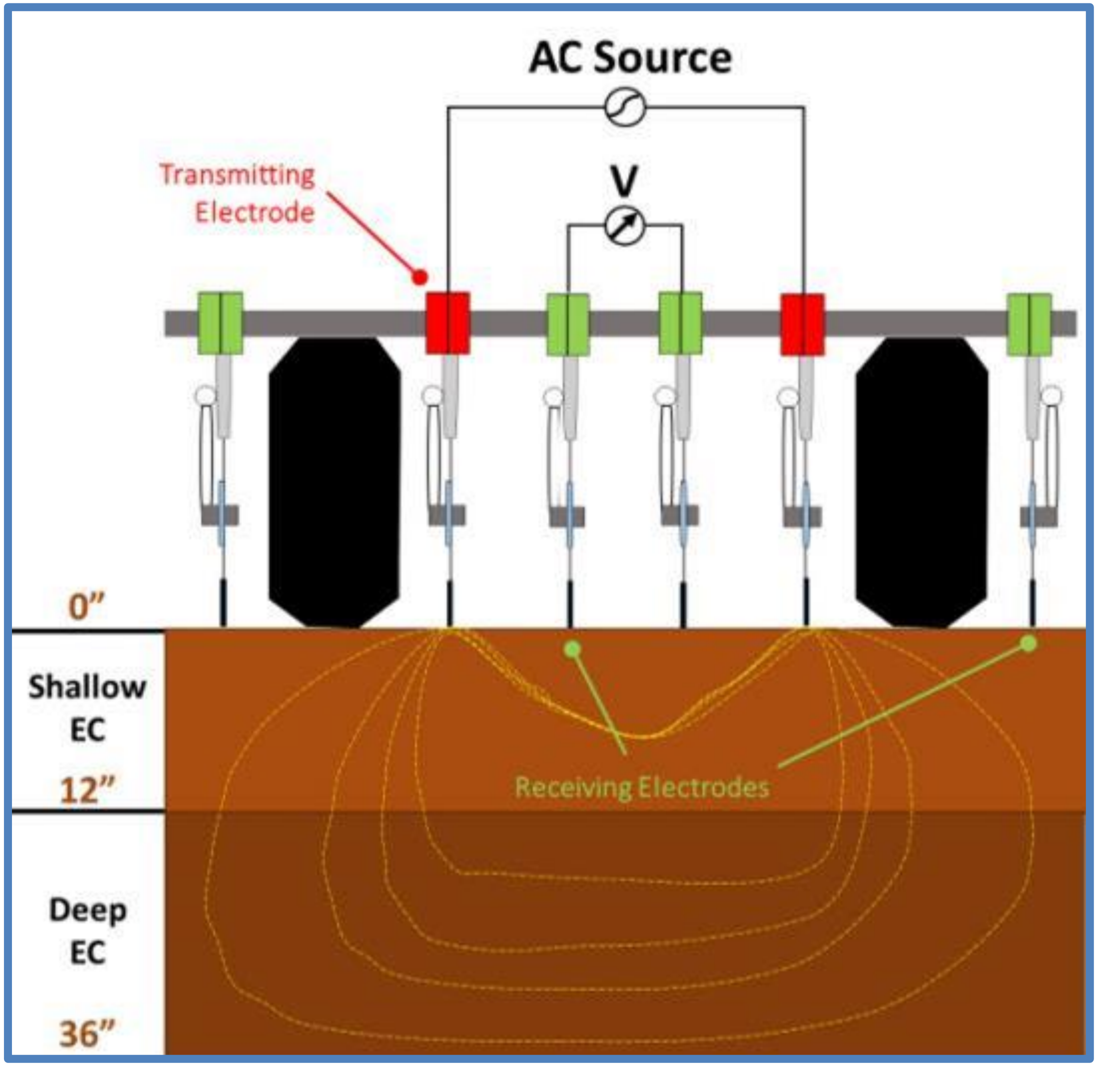
Soil EC Contact Sensors



Source: Grisso et al.. 2009

Soil EC Contact Sensors

- Veris systems can measure EC at either a single depth or at two different depths, depending on the coils' positioning and number.



Source: ohioline.osu.edu

Proximal Reflectance Sensors

- Sensors that collect spectral reflectance data at ground level.
- These type of sensors obviously offer the highest possible accuracy compared to satellite and drone data.
- Proximal reflectance sensors are often used to validate the accuracy of a remote sensing datasource.

Proximal Reflectance Sensors

- Data is either collected manually, or as the sensor is mounted on an agricultural vehicle and scans the field, logging values at a predetermined interval.
- Each measurement is stored along with positioning data of each spot in order to create georeferenced data that represent the value of each point.

Proximal Reflectance Sensors

Agricultural vehicles mounted with reflectance sensors.

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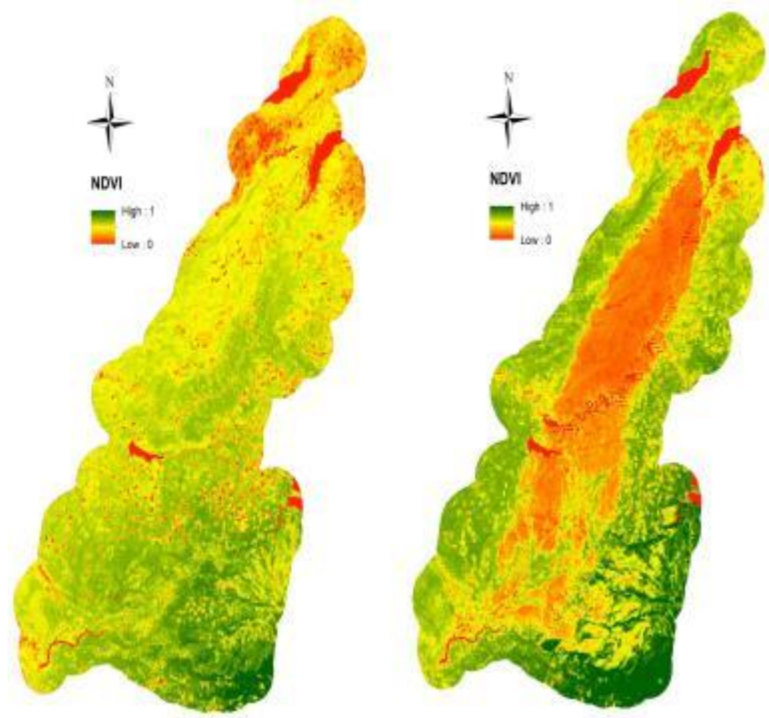
Variable Rate Application

Reflectance and vegetation indices can provide insights on crop vigor, and can therefore be used to adjust fertilization.

Real Time → Mounted Sensors

Prescription → Loading an application map



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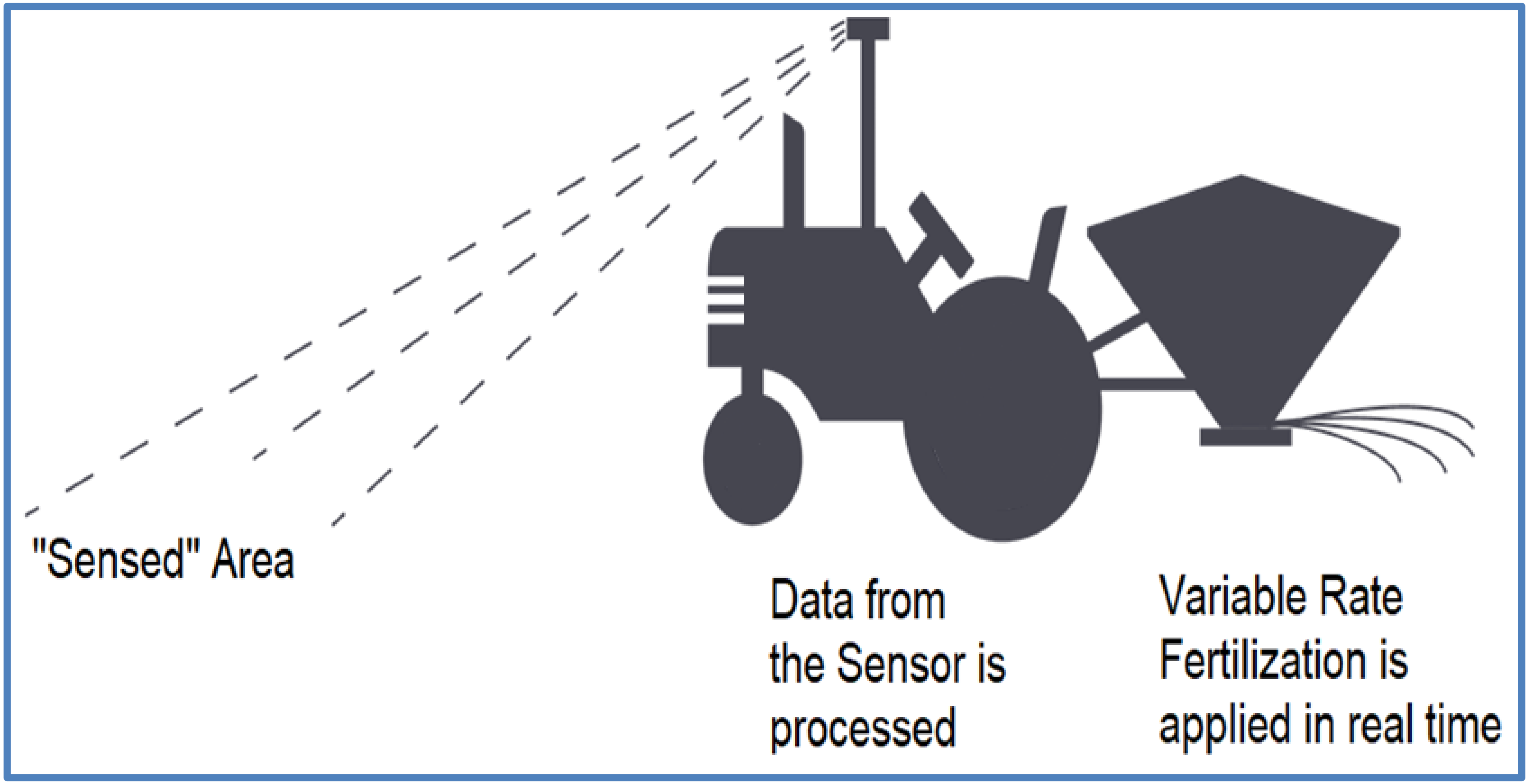
Real Time Fertilization Systems

Systems able to calculate the nutritional needs of the plants in real time and apply appropriate fertilization.

Real Time Fertilization Systems



Yield Monitoring

- Economical profit or loss from each growing season depends on the final yield and quality of the products.
- Both yield and quality characteristics are the result of several factors, both biological and abiotic, as well as numerous interactions (i.e. crop-environment).
- For this reason yield characteristics demonstrate high spatial variability even inside small fields.

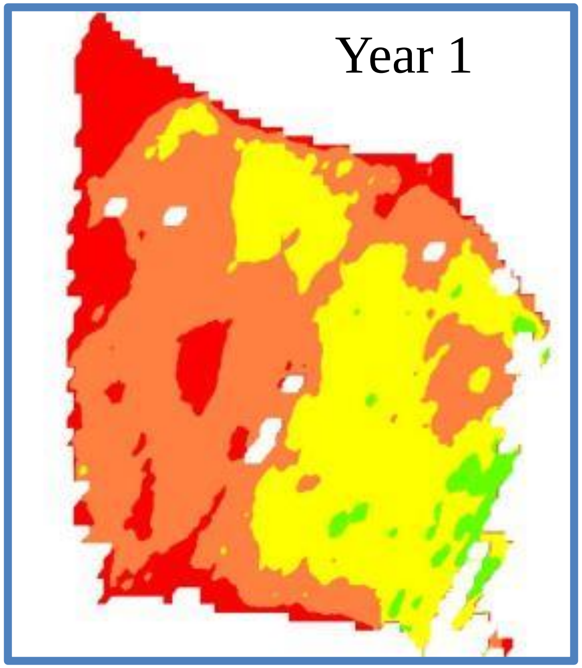
Yield Monitoring

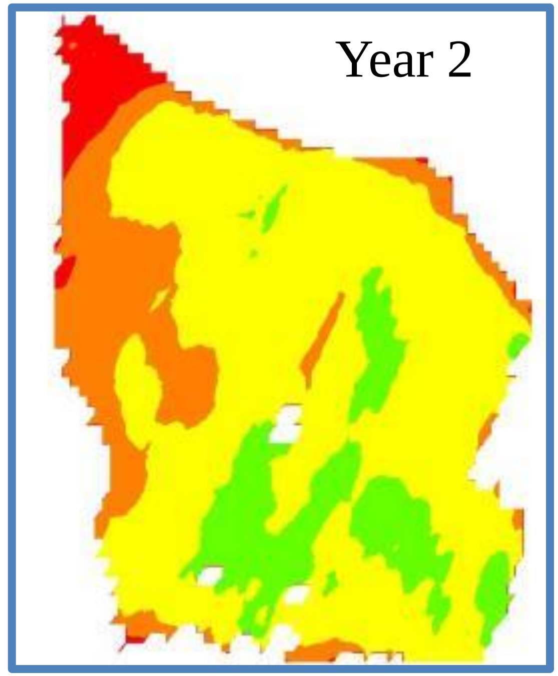
- These yield variability observations are what led to the emergence of an early Precision Agriculture concept in the 1980s.
- Certain areas inside the field might produce high yield and be profitable, while others perform so poorly that end up as a financial burden since the profit is less than the cost of their cultivation.

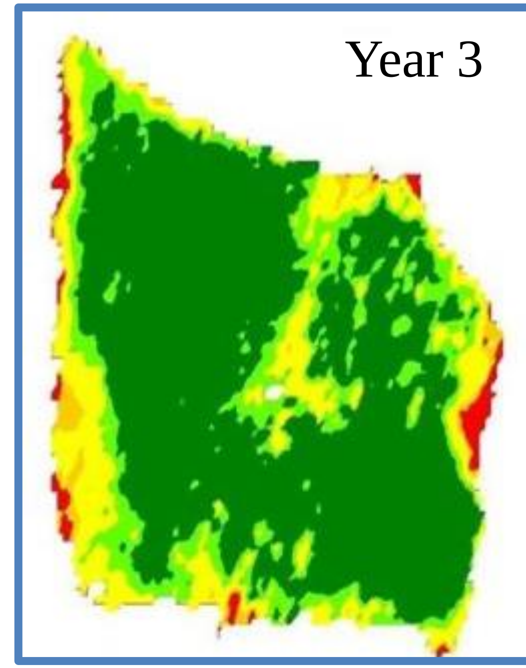
Yield Monitoring

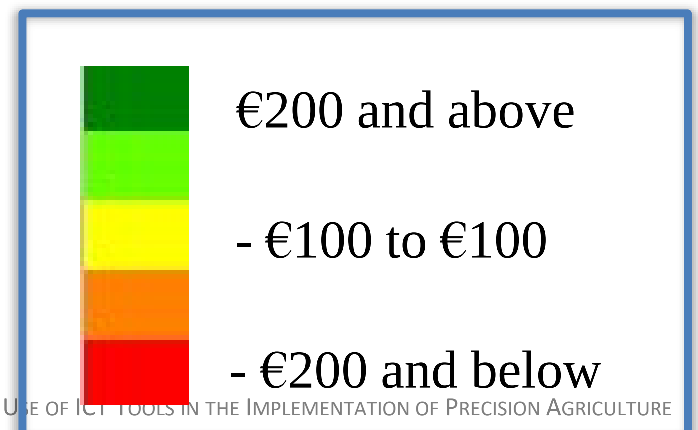
- High productivity zones loose large amount of nutrient each growing season, while low productivity zones cannot fully utilize inputs applied to them, resulting in economical losses, environmental pollution and plant toxicities.
- With knowledge on the productivity of each zone, farm practices can be adjusted to ensure that the high productivity of the high-yield zones is maintained, while low productivity zones are aided or offered what the need.

Yield Maps









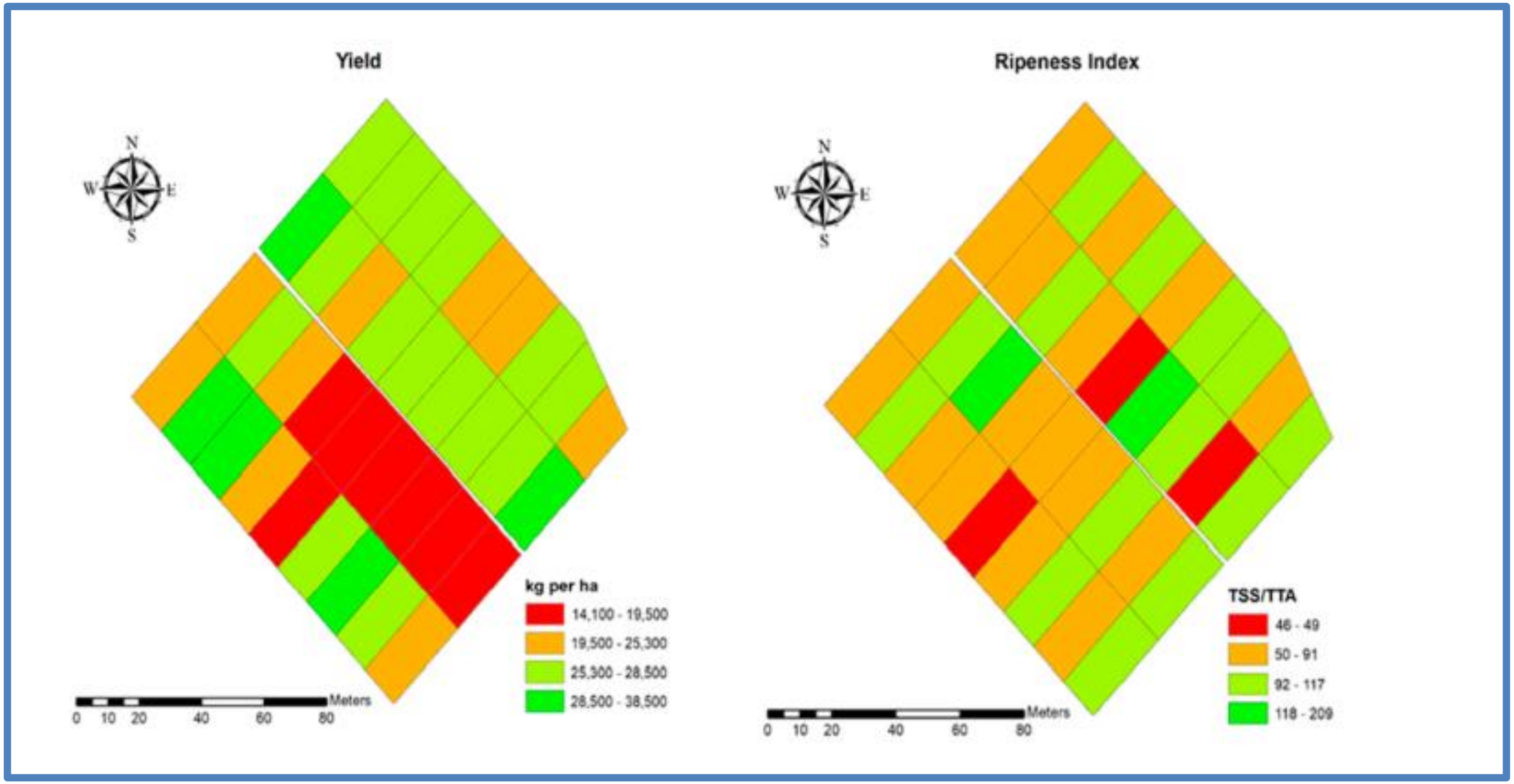
Yield Maps

- Georeferenced yield data is one of the most accessible and valuable information that a farmer can obtain.
- Yield maps and simple crop calendars from different years can easily indicate factors that are responsible for yield reduction or increase, while generating an extremely valuable historical database.

Yield Maps

- The methodology is that the field is divided into smaller georeferenced segments (grids).
- Yield is then measured is this grids, and samples from each parcel are also collected.
- The samples are then analyzed to obtain information on the qualitative characteristics of the yield, so that finally potential correlations between factors can be studied.

Yield Maps



Source: Anastasiou et al., 2018
doi.org/10.3390/agriculture8070094

Yield Sensors

- Yield mapping systems are based in yield sensors placed inside yield harvesters.
- Several types of sensors are used, from simple weighting loading cells in the grain elevator to optical sensors that estimate volume flow and yield characteristics.
- Sensor data and positioning data are combined by the Central Computer Unit and Yield Maps are generated.

Agr ICT

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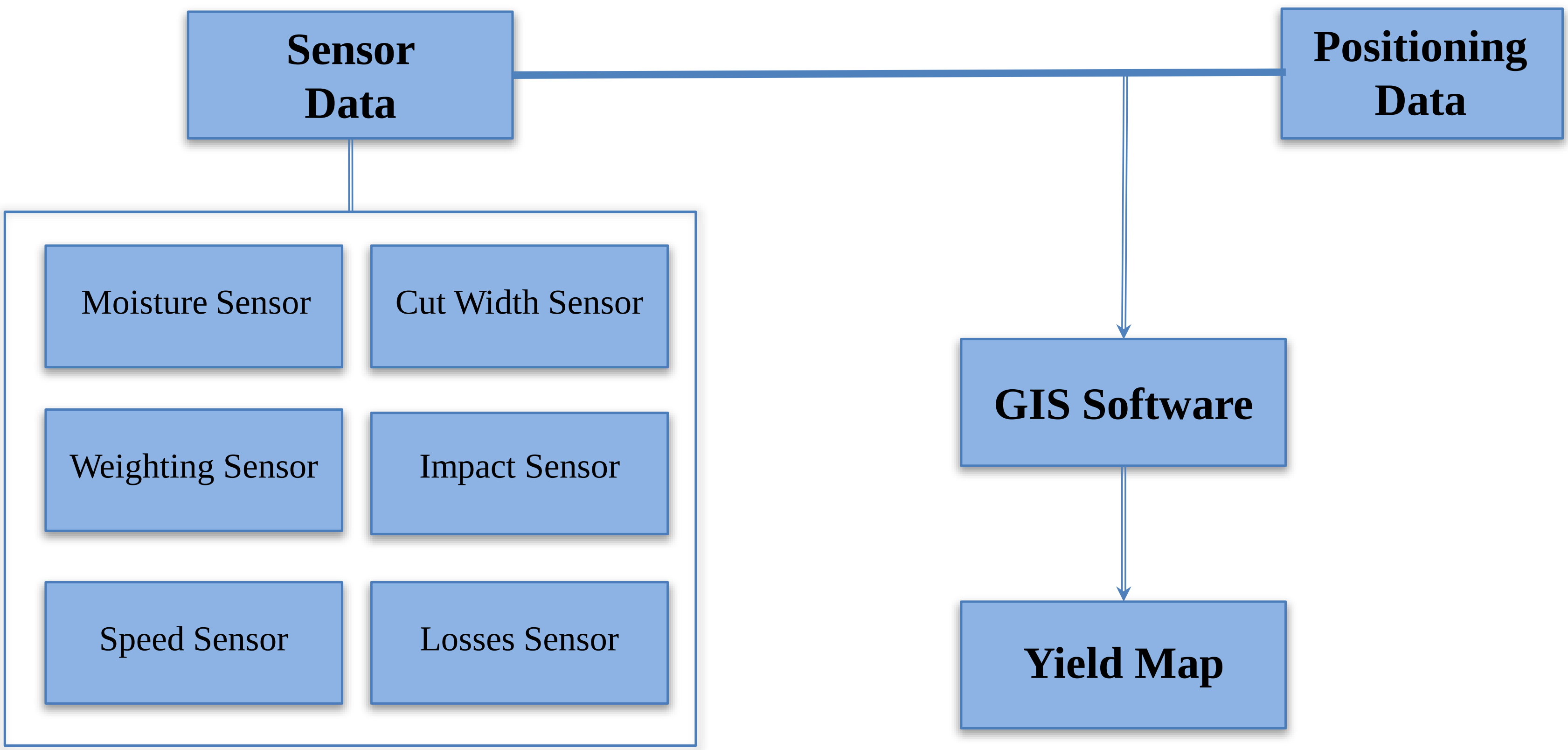
Yield Sensors

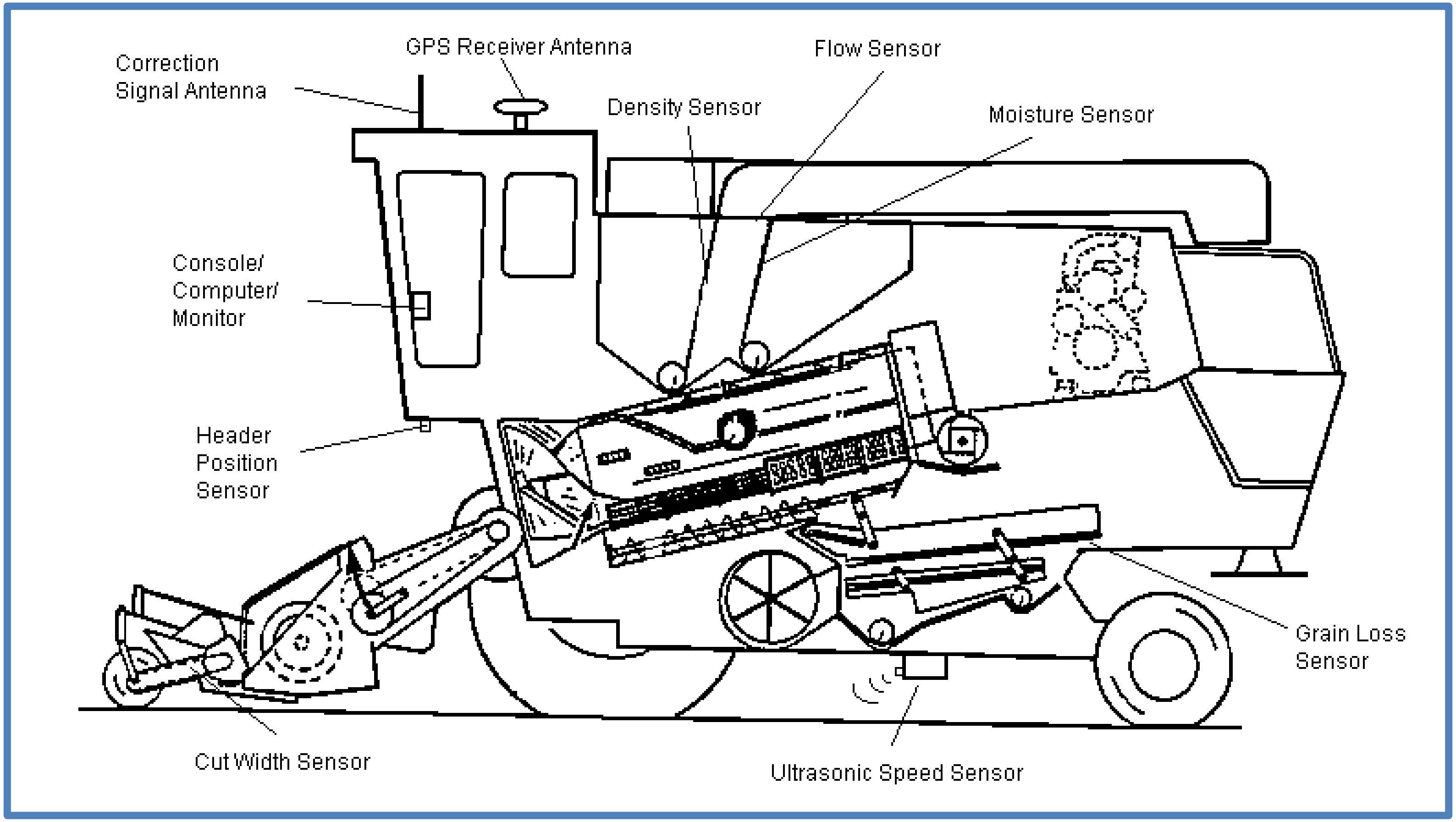
Principles of function:

- Weighing measurements (i.e. flow weigher, grain tank weigher and conveyor weigher)
- Volume measurements (i.e. grain tank filling level)
- Impact measurement (i.e. impact plate)
- Indirect methods (i.e. NIR sensors)

Yield Sensors



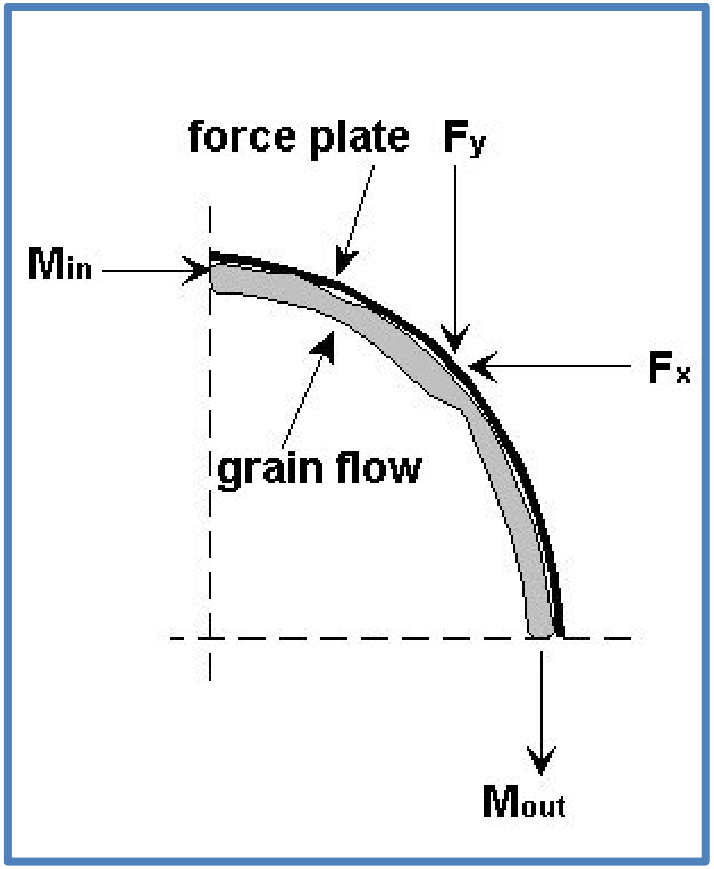
Yield Sensors



Source: Keshin et al., 1999

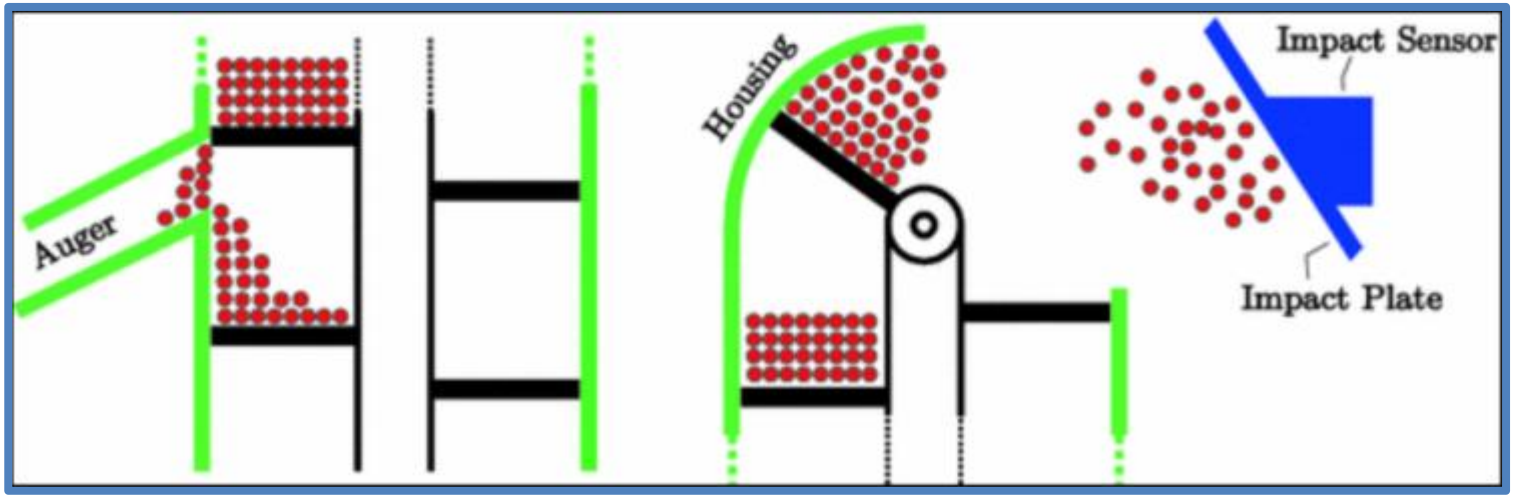
Yield Sensors

- Force Plate Sensors are one of the most widely used types of grain yield sensors in the world.
- Measure the force of grain thrown by the clean grain elevator and calculates yield.
- The measured force is of course calibrated to yield weight. Proper calibration in yield sensors is of outmost importance.



Yield Sensors

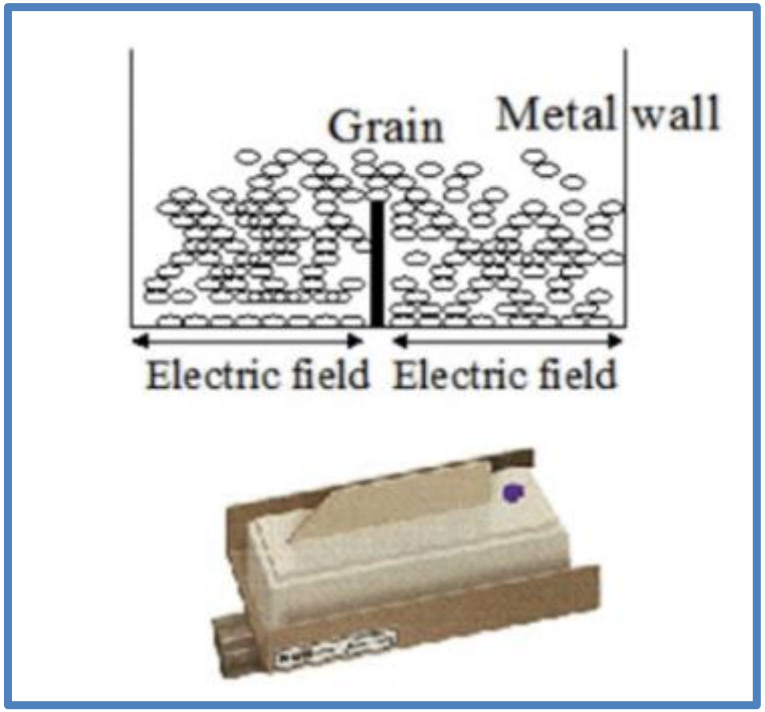
- In mass flow yield systems, grain enters the system from and auger and is deposited onto elevator paddles.
- The elevator paddles are attached to a chain that rotates the paddles, propelling grain toward an impact plate which measures impact force



Source: Reinke et al., 2011.
doi.org/10.1007/s11119-010-9215-0

Yield Sensors

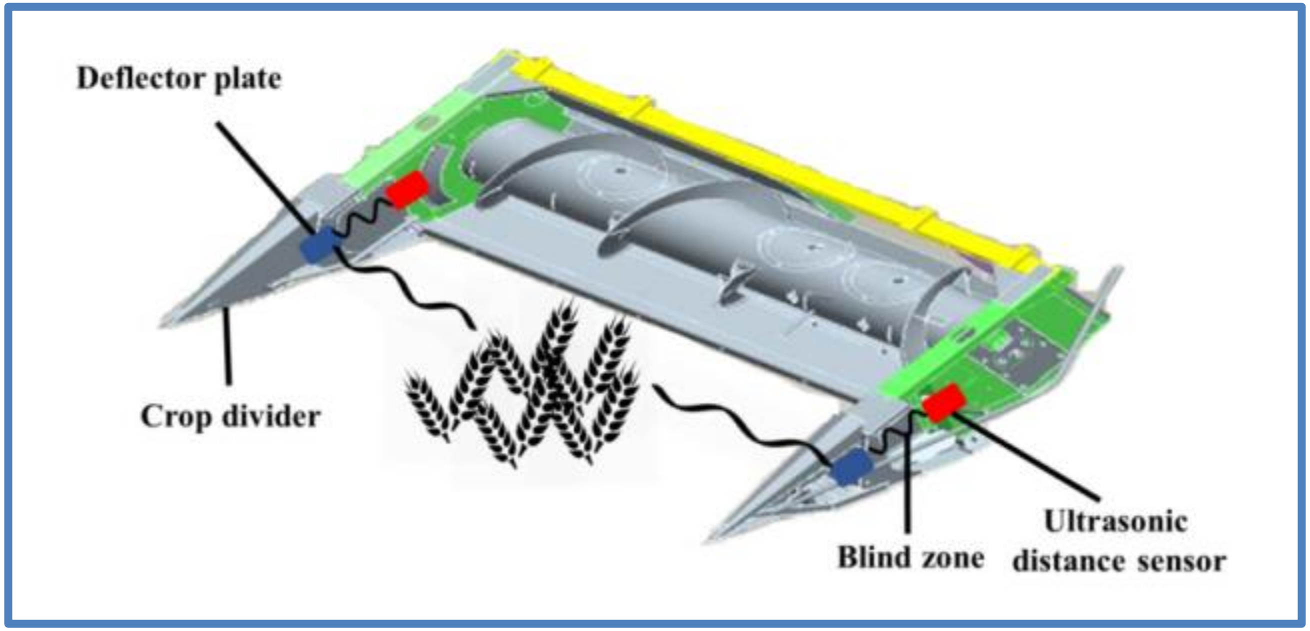
- Grain moisture measure yield water content. The sensors may have a blade or flat surface, and are mainly mounted on the grain auger surface.
- Moisture sensors measure the amount of current that flows through the grain held between the two electrodes of the system.



Source: Chung et al., 2006.
doi.org/10.5307/JBE.2016.41.4.408

Yield Sensors

- In the cutting width sensors, the time required for the ultrasound signal to travel from the transmitter to the receiver is used to calculate the cutting width.



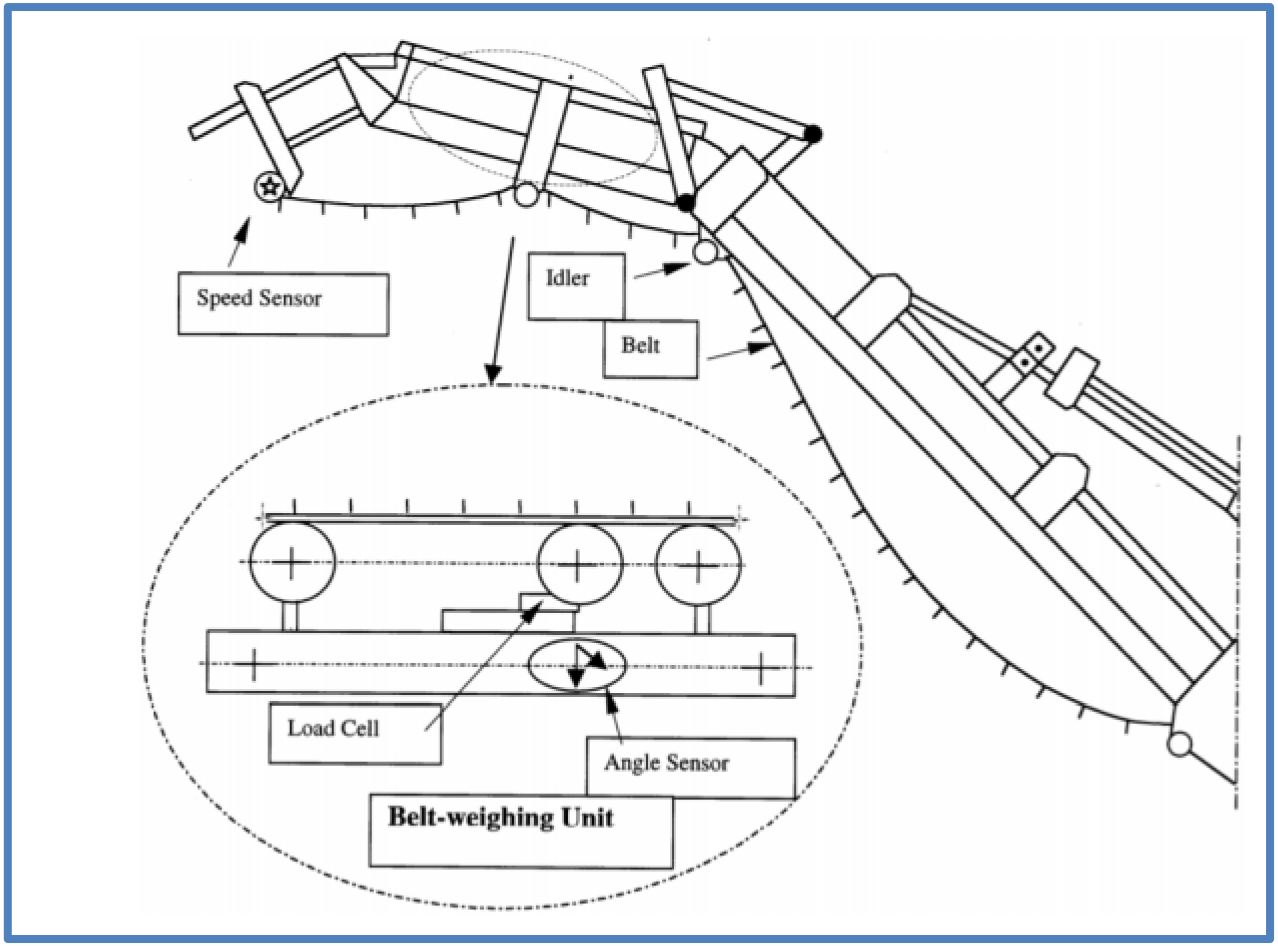
Source: Chung et al., 2006.
doi.org/10.5307/JBE.2016.41.4.408

Yield Sensors

- Yield monitoring in horticultural crops is mainly performed with weighting systems installed in the conveyor belts of the harvesters.
- These systems use continuous belt-weighing type load monitors mounted on the boom elevator of the harvesters.

Yield Sensors

A tomato yield monitoring system



Source: Pelletier & Upadhyaya, 1999
doi.org/10.1016/S0168-1699(99)00025-3

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Stationary Sensors

- Stationary sensors can vary, from simple weather stations that record atmospheric temperature and rainfall, to state-of-the-art platforms incorporating a wide variety of sensors intended for the continuous surveillance of cultivation environment variables in agricultural areas.
- These sensing systems focus on collecting **atmospheric** and **solar** measurements, as well as measurements regarding the cultivation's **soil** parameters and other abiotic parameters related to the growing parameters of the plants.

Stationary Sensors

Atmospheric

- Temperature
- Relative Humidity
- Barometric Pressure
- Wind Direction
- Wind Velocity
- Solar Radiation

Soil

- Moisture
- Salinity/Conductivity
- Temperature
- Leaf wetness

Stationary Sensors

Gaiasense IoT Station with Soil Sensors (Neuropublic S.A.)

Stationary Sensors

- Stationary sensors that are used to record a certain parameter throughout the growing season. They are installed inside cultivated fields and left there for years with minimal or, if possible, no maintenance whatsoever.
- This means that they will remain exposed at the field during heavy rainfall and for extended periods directly hit by sunlight, which they should be able to withstand.

Stationary Sensors

- Therefore, major importance should be given to the **station parts**, since all components should meet the demanding requirements regarding resistance to field conditions / climate of each region.

Stationary Sensors

The resistance requirements of the sensors naturally depends on several factors, such as the climate/microclimate of each field. However, as far as weather and general external conditions are concerned, all the exposed parts should be able to withstand:

- Temperatures ranging (i.e. from -15 to +50ºC).
- Exposure to direct sunlight for prolonged time periods, approx. 10 years (UV resistance).
- Prolonged operation under high atmospheric humidity (100%).
- Extreme rainfall and hail.
- High wind speeds (over to 100 km/h).

AgrICT

Development of a Training Program for Enhancing the Use of ICT Tools in the Implementation of Precision Agriculture

Project coordinator

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