‘Bemestingstechnieken maken het verschil’
Fertilizer technology makes a difference

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EU farmers/ farm managers by age group, 2013
**20:20 Wheat®**

20:20 Wheat® aims to provide the knowledge base and tools to increase wheat yield potential (in the UK) to **20 t.ha⁻¹** within the next **20 years**.

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**Crop growth…..**

- Crop growth can be
  - Potential growth (all conditions optimal)
  - Limited growth (for example shortage of N, water,...)
  - Reduced growth (pests and diseases, weeds,...)
- Problem is to determine the potential growth and which are the limiting or reducing factors
- Limiting and reducing factors may vary from place to place in a field
Precision Agriculture: Management Scales & Approaches

- **Conventional Farming & Traditional Management**
  - Field scale & One rate

- **Precision Farming & Site Specific Management**
  - Sub-Field & Variable rate

- **Single-Plant-Care & Robotic Management**
  - Single Plant Individual rate
Management cycles in agriculture

- LONG cycles: soil structure & fertility
- YEARLY cycles: soil prep., crop growth and Nitrogen
- SHORT cycles: weeds, insects, diseases, irrigation, harvest
- 24 hour cycles: mites in citrus, storms & hail

Smart farming: analysis and information

- Correct observation: visually, sensors…
- Correct documentation (soil, previous crops and treatment…)
- Correct analysis
Smart farming: decisions

- Correct genotype
- Correct dose
- Correct chemical/biological compound

Smart farming: actions

- Correct place
- Correct time
- Correct (climatic) conditions
- Correct (use of) equipment
Innovations: from descriptive to prescriptive

- Sensing and monitoring
- Data handling and storage
- Information collection and decision support
- Deployment and implementation

Stanca: Club of Bologna 2015
Proximal sensing of spatially variable soils

1. **electrical and electromagnetic sensors** measure electrical resistivity/conductivity or capacitance affected by the soil composition.

2. **optical and radiometric sensors** use electromagnetic waves to detect the level of energy absorbed, reflected, or emitted by soil particles.

3. **mechanical, acoustic, and pneumatic sensors** measure spatially variable interaction between a measuring tool and soil.

4. **electrochemical sensors** use ion-selective material, producing a voltage output in response to the activity of selected ions.

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**Topsoil Mapper**

- Non-contact system for measuring soil parameters in real time.
- Automatically detects a range of soil parameters:
  - compacted patches,
  - degree of saturation with water and
  - soil type,
- Transmitter and receiver coils detect:
  - the apparent conductivity down to a depth of 1.1m.
  - software prepares 3D soil maps

Development of a sensor-based fertiliser (P) applicator

- **Optical Soil sensor** to gather the soil P information
- **P model** to predict soil P from fresh soil;
- Implementation on field machinery

Laser Induced Breakdown spectroscopy

- Soil nitrogen, and phosphorus: with LIBS using a sample chamber under a partial vacuum or argon purge and optimizing instrumentation for each specific element (1)

- NERCITA, China, at an August 2017 meeting announced a portable LIBS tool for N with a measurement duration of 2 sec.

(1) R.D. Harris et al., Measuring Soil Carbon and Nitrogen Using Laser-Induced Breakdown Spectroscopy (LIBS). Los Alamos National Laboratory, Los Alamos, NM 87545
Plant-microbe interaction

- Beneath the surface of the earth, an influential community of microbes mingles with plant roots
- Spatial variability in available substrate and environment for soil microbial activity
- Spatial heterogeneity of microbial activity has received less attention to improve local soil (and crop) management
manage agriculture to achieve benefits aside from just productivity?

IPN 4R method for Phosphorus management
IPN: International Plant Nutrition Institute

- Right Source
- Right Rate,
- Right Time
- Right Place).

http://phosphorus.ipni.net/ipniweb/region/nane.nsf/0/1B2DE95D06B8C1E08525813B004DA51D/$FILE/Bruulsema%20CSSS%202017.pdf
Precision fertilization with manure

\[
y = 0.7965x + 1.6667 \\
R^2 = 0.8596
\]

- Planning and optimization with a holistic, overall observation of the harvest history and includes technologies for highly precise fertilizer application.
- Farmers will be able to precisely determine, apply and document nutrient demands (nitrogen, phosphates etc.) for specific sub-areas, regardless of the type of organic or artificial fertilizer used.
- Since nutrient distribution is optimized according to sub-area demands and vegetation times,
- It provides a higher level of nutrient efficiency and also optimizes nutrient balances.

Connected Nutrient Management

Root development: scale of nutrient use

Root system of sweet corn 16 days after planting. The growth of the secondary root system is well under way.

Root system of sweet corn 8 weeks old.

JOHN E. WEAVER and WILLIAM E. BRUNER, ROOT DEVELOPMENT OF VEGETABLE CROPS. McGRAW-HILL BOOK COMPANY, Inc. NEW YORK, LONDON. 1927

Root development: scale of nutrient use

Alfalfa plant 63 days old.

Alfalfa root 4.5 months old.

Two-year-old alfalfa root grown in rich lowland soil. Water table at depth of 12 feet.
Variety selection in precision agriculture
Matching root morphology to soil conditions?

New equipment challenge…?
New management challenge….?

Fertiliser N requirements

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\text{Fertiliser N requirement (kg ha}^{-1}) = \frac{\text{CND (kg ha}^{-1}) - \text{SNS (kg ha}^{-1})}{\text{FNR (\%)}},
\]

Fertiliser N from knowledge of three components:
- Crop N Demand (CND) by optimized crop,
- Soil N Supply (SNS) in absence of fertilizer
- Fertiliser N Recovery (FNR), % N applied into the optimised crop.

Nitrogen Use Efficiency: at field scale?

Possible targets
- NUE = 90%
- Desired maximum N surplus < 80 kg/ha/yr
- NUE = 50%
- Desired minimum productivity (N output > 80 kg/ha/yr)

N output, kg/ha/yr

EU Nitrogen Expert Panel (2015) Nitrogen Use Efficiency (NUE) - an indicator for the utilization of nitrogen in agriculture and food systems. Wageningen University, Alterra, PO Box 47, NL-6700 Wageningen, Netherlands.
Nitrogen or chlorophyll content in canopies or leaves

- Tissue analysis
  - Kjehdahl
- Electrical meters
  - Nitrogen ion selective electrodes
  - Electrical impedance spectroscopy
- Leaf level optical measurements
  - Leaf transmittance (SPAD)
  - Chlorophyll fluorescence (polyphenols-Dualex, Multiplex)
- Canopy level reflectance measurements
  - Ground based active or passive sensors
  - UAV or airplane
  - Satellite

Active optical sensors for N

- Yara N-Sensor
  - Absolute-N calibration (based on crop model and other information), or
  - Rolling calibration during operation
- Greenseeker
- OptRx Crop Sensors, based on a virtual reference strip.
UAV-unmanned aircraft for crop monitoring: weeds, disease, growth,

Potato plant health and biomass monitoring using UAV and hyperspectral camera

MTT and VTT Finland
Vegetation index and crop diseases

- Optical sensing, using reflectance, fluorescence or thermal imaging can detect diseases at early stages for mapping to drive control strategies. Moshou D, et al. 2011
- Vegetation indices were suitable to detect differences in the reflection between healthy and diseased plants.
- But there was no specific vegetation index for only one of the diseases.
- Also the sensitivity of the indices was not very high.
- More vegetation indices have to be tested.

Use of Vegetation indices to detect plant diseases. Kerstin Gröll, Simone Graeff, Wilhelm Claupein Institute for Crop Production and Grassland Research, Hohenheim, Germany

Variable Rate Fertilizer Application
Need for appropriate equipment for precision crop production

Plant to Plant Variability

• Some management related causes of plant to plant variability:
  o Deviations in planting depth and seed spacing,
  o Uneven nutrient application and crop residue distribution,
  o Wheel-track compaction,
  o Weed competition,
  o Plant population level.

(Andrade and Abbate, 2005), (C. R. Boomsma, T J. Vyn, 2010)
Plant to Plant Variability

- Environment-related causes of plant to plant variability:
  - Variations in insect feeding
  - Variations in disease pressure
  - Micro-climate variations
  - Inherent soil spatial variability (Andrade and Abbate, 2005).
  - Soil moisture and temperature effect on seed emergence
- No-tillage farming: more risk for this plant-to-plant variability

Account for plant and row variability

- Yield monitors don’t characterize variability at plant or row level
- Many potential causes, but uneven fertilizer delivery/availability is likely involved
- Recognize that early plant roots don’t extend very far
- Corn is often unable to recover from short periods of nutrient stress during early season
Precision near row placement

N-fixation technology can help…

Yield of wheat inoculated with NFix® against uninoculated controls in an independent N fertilizer trial

Precision Agriculture Environmental Benefits: N-fertilizer use

Process:
- Nitrogen fertilizer application for optimal crop growth and production

PA Technology:
- Crop vegetation index based on optical sensors
- Soil nutrient maps, crop models
- Variable rate nitrogen fertilizer application according to crop requirements and local conditions

Expected benefits:
- Improvement of nitrogen use efficiency.
- Reduction of residual nitrogen in soils by 30 to 50%.

Precision agriculture and environment

- Precision agriculture tools and concepts enable reduction of environmental impact of agriculture.
- Optimizing G.A.P. based on PA:
  - Reduction of fungicide use versus increased mycotoxin risk
  - Optimal fertilizer use versus total biomass and mycotoxin risks
  - Reduce crop damage from pest for reduced fungal infections
- PA is the road towards optimal use of inputs for food production:
  - Can also lead to optimal land use whereby secure food supply is possible using only the most productive land
  - To certify that a farmer is operating in the framework of environmentally friendly good agricultural practices

G.A.P. = Good Agricultural Practices
Precision agriculture implementation challenges

How do we translate precision agriculture advances:
• into feasible techniques (not necessarily only large complex machines)
• practiced by trained farmers around the world
• irrespective of the scale of farming?

G x E x T x M

Precision agriculture: optimize the combination of
  - Genetics
  - Environment
  - Technology
  - Management

Precision agriculture as a mindset
Large amounts of data require knowledge analytics, for farm information, integration and decision making. Check on the execution.

The Vision by J. v. Liebig

"... One day (it was around 1850) Liebig said:

The farmer will be able to assess the exact yield during harvest like a bookkeeper is doing in a well controlled factory; then by simple calculations he could determine highly precise all substances which he has to replace in each field, also by amount, to restore the fertility (85).

→ "Precision Farming by Balance on Field-scale"!

Wheat Yield 1986 Leuven