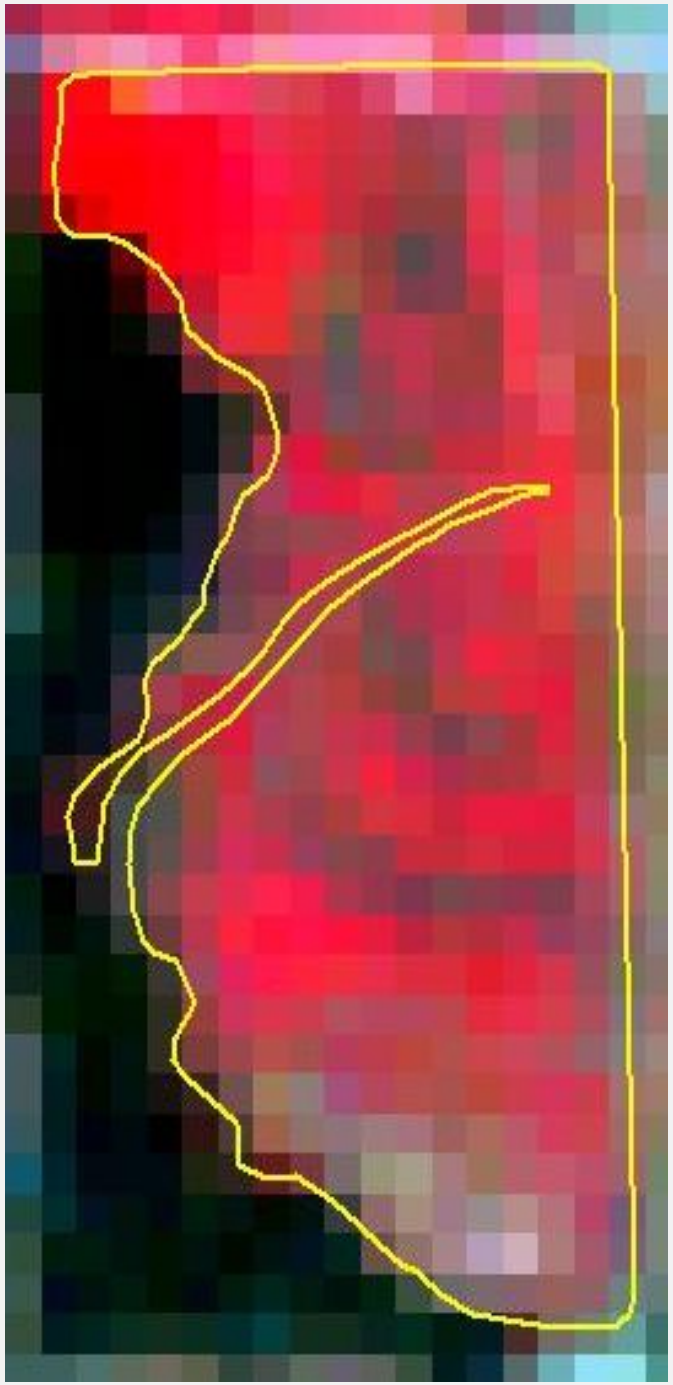


Soil Moisture Sensing and Precision Agriculture

Dr. Paul Weckler, P.E.

Biosystems & Agric. Engineering Dept.
Oklahoma State University

Soil Moisture Sensing

- **Why?**

Soil Moisture Sensing

- **Why? --- Machine automation**

Sensing for Machine Automation

- **Why?**
  - **Plant by plant management** (***the future of precision ag***)
    - **Nutrients**
    - **Pests & disease control**
    - **Irrigation**
  - **Precision planting** **--Plant seed into adequate moisture**

Variable Depth Planting of Corn
Rene-Laforest, F., V.I. Adamchuk, M.A. Mastorakos, N.M. Dhawale, and Y. Su. 2014
ASABE Paper No. 141912822.

Sensing for Machine Automation

- **Why?**
  - **Autonomous vehicle operation**
    - **Avoid wets spots….., don't get stuck**
- **Resolution desired**
  - **Sub-meter in x & y (preferable at centimeter level)**
  - **Look ahead capability**
  - **Entire root zone**

Kinze Autonomous Harvest System

Various Technologies for Sensing Soil Water

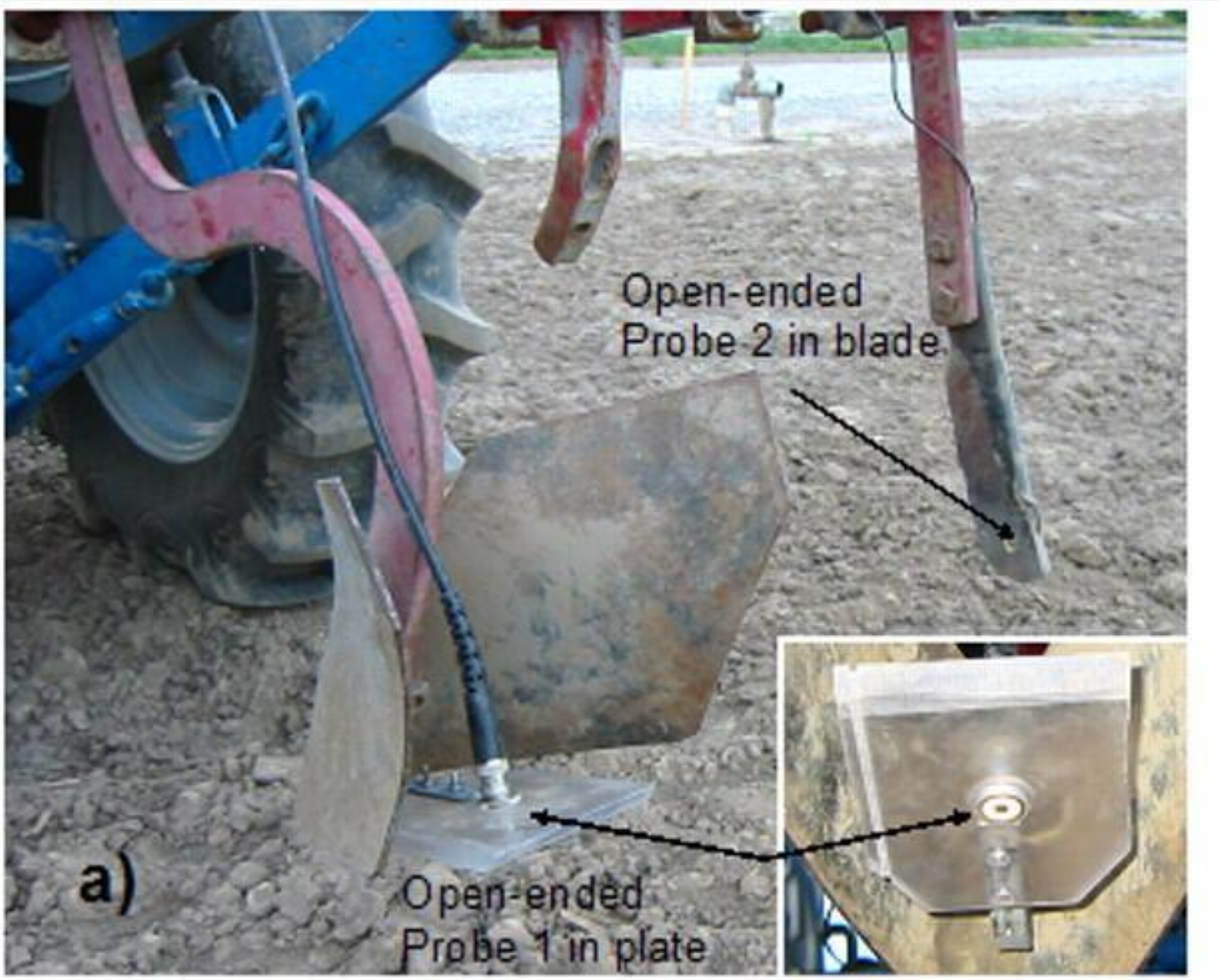
- EM / Dielectric reflectance or absorbance
  - RADAR technologies (ground penetrating RADAR)
    - Impulse
    - stepped frequency
    - Frequency modulated continuous wave (FMCW)
    - Noise
  - Microwave backscattering
  - Un-modulated continuous-wave
    - Finite-difference time-domain (FDTD)
- Radiation scattering
  - Neutron scattering
- Optical / Thermal

In situ dielectric soil water probes

- **Require:**
  - Disturbance of the soil profile for burial
  - Cost of excavation
  - Removal after growing season
- **Advantage**
  - Low-cost
  - Signal readily transduced for logging

http://www.decagon.com/products/sensors/soil-moisture-sensors/

Soil Water Sensors (China Ag Univ)

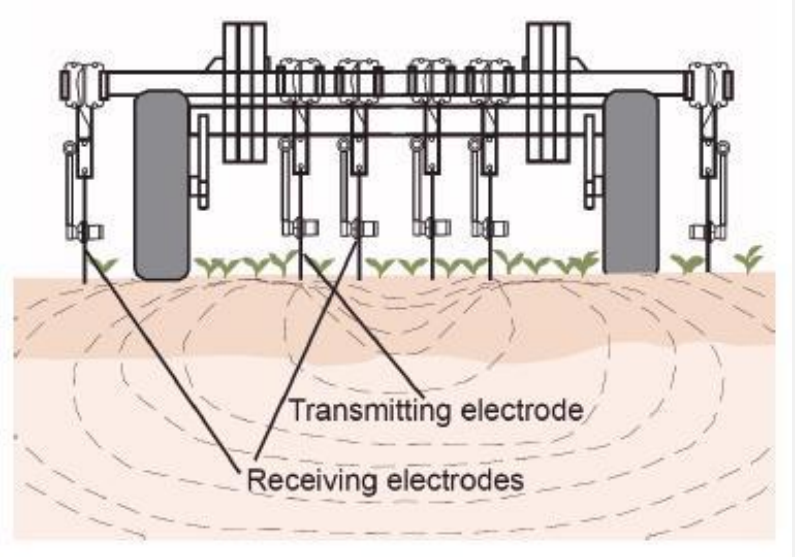


Scott B. Jones, David A. Robinson and Shmulik P. Friedman. **Development of a subsurface open-ended TDR probe for on-the-go mapping of water content**. Proceedings TDR 2006, 3rd Int. Symp. and Workshop on Time Domain Reflectometry for Innovative Soils Applications, Purdue University, West Lafayette, IN. 17–20 Sept. 2006. Available at https://engineering.purdue.edu/TDR/

Soil Electrical Conductivity Sensors

- **Contact Sensors**
  - Soil EC Sensor
  - Mobile Sensor Platform
    - w/ pH Manager

- Veris Technology manufactures a contact type of EC measuring device.

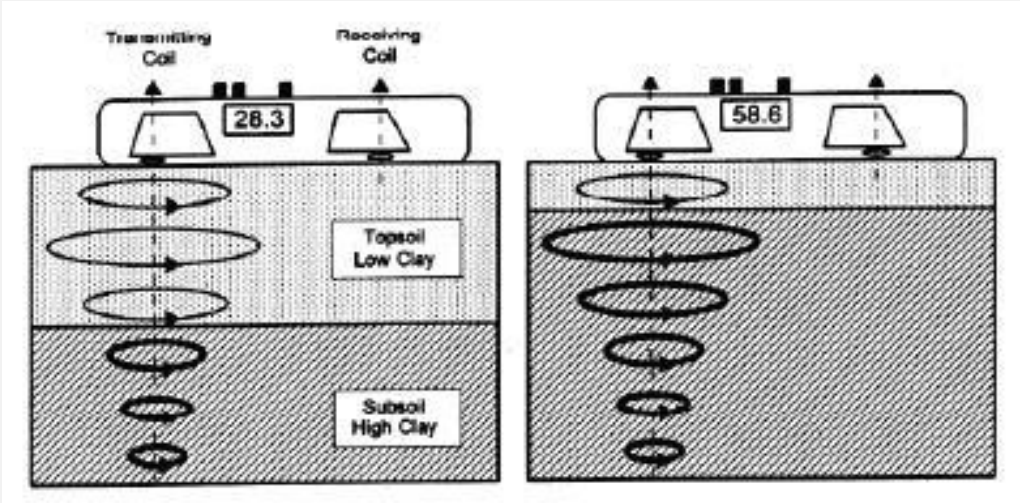


Soil Electrical Conductivity Sensors

Non-Contact EC Sensors

Non-contact EC sensors work on the principle of electromagnetic induction

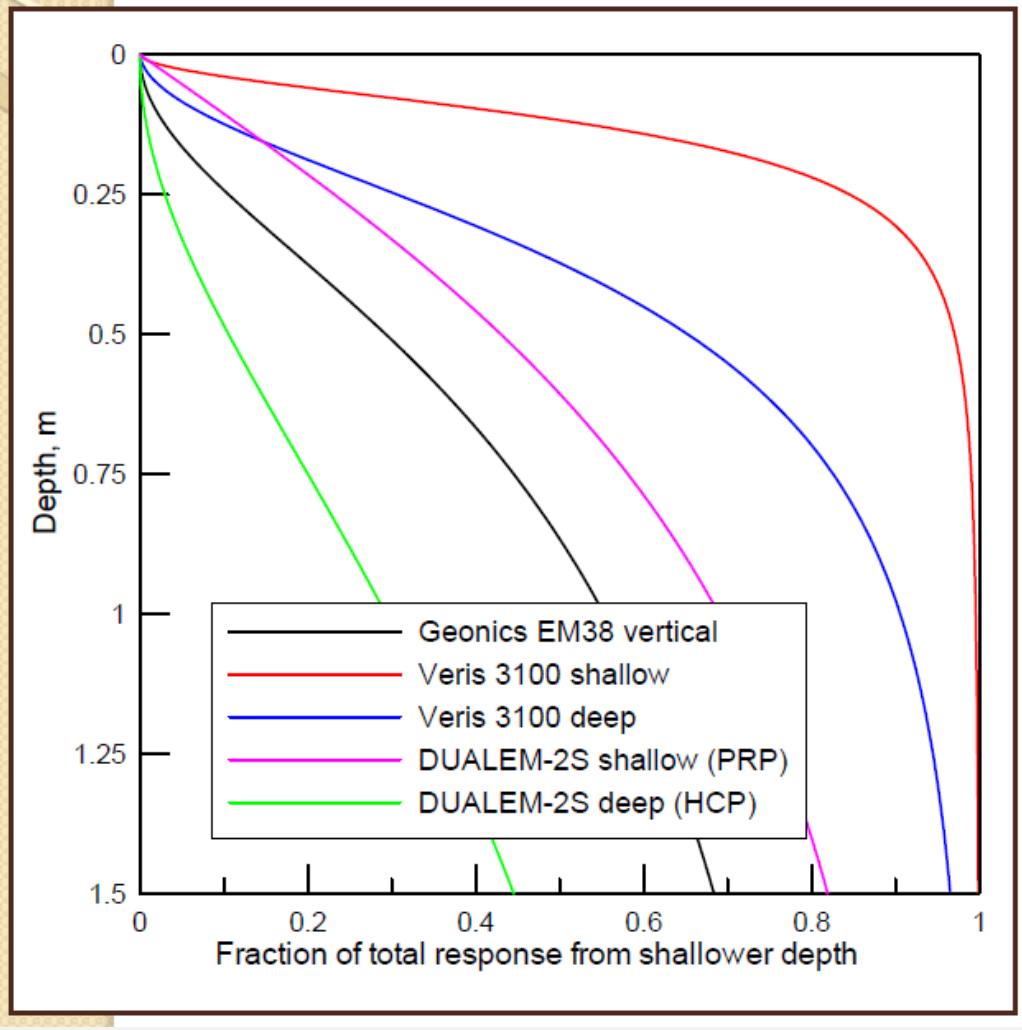
M38 (Geonics Limited) and GEM-2 (Geophex) are two popular models of non-contact sensors.



Commercial EC_a sensors

Ken Sudduth, 2013. Crop and Soil Sensors for Precision Agriculture, Proceedings of ACPA

Sensors provide information about different soil depths



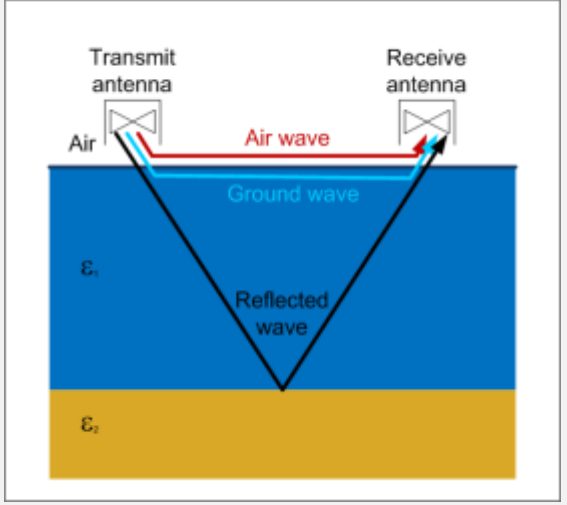
Depth for 90% of total response:

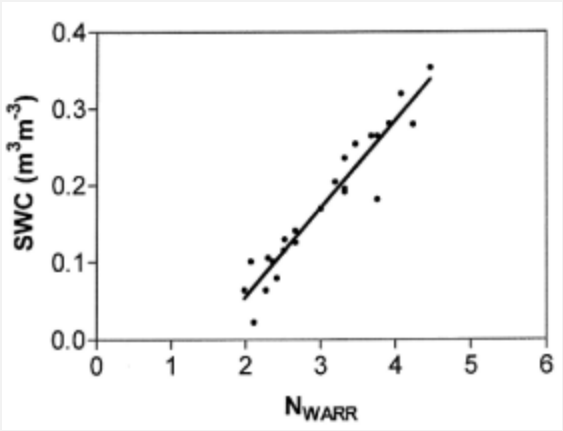
- Veris shallow: 0.3 m
- Veris deep: 1.0 m
- DUALEM shallow: 2.2 m
- EM38: 5 m
- DUALEM deep: 10 m

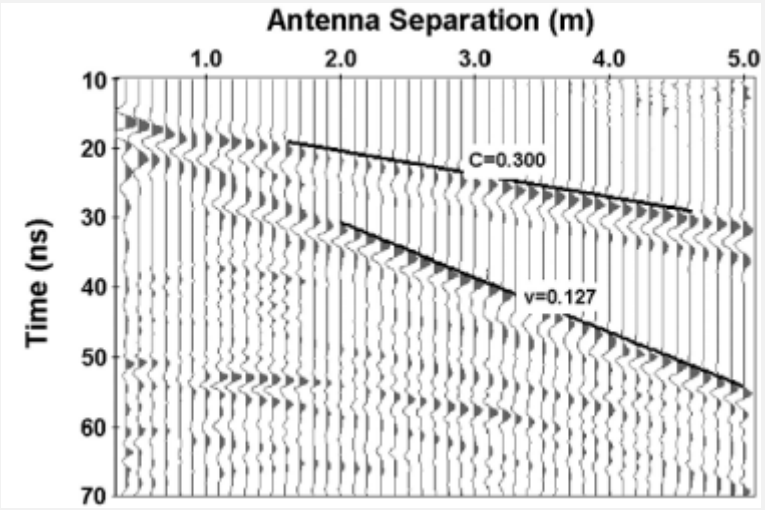
Ken Sudduth, 2013. Crop and Soil Sensors for Precision Agriculture, Proceedings of ACPA

Ground penetrating RADAR

- Based on time delay of the reflection of electromagnetic waves
- Velocity of electromagnetic wave is a function of permittivity which is a function of moisture content
- Ground wave and air wave velocities are used to determine Refractive index (N_{warr}) and then SWC
- Effective for SWC in upper soil layer (10-20 cm)
- Low cost components available







Huisman, J. A. , S. S. Hubbard, J. D. Redman and A. P. Annan. 2003. Measuring Soil Water Content with Ground Penetrating Radar. *Vadose Zone J.* 2(4): 476-491. SSSA.

Large area soil moisture monitoring using ground penetrating radar (GPR)

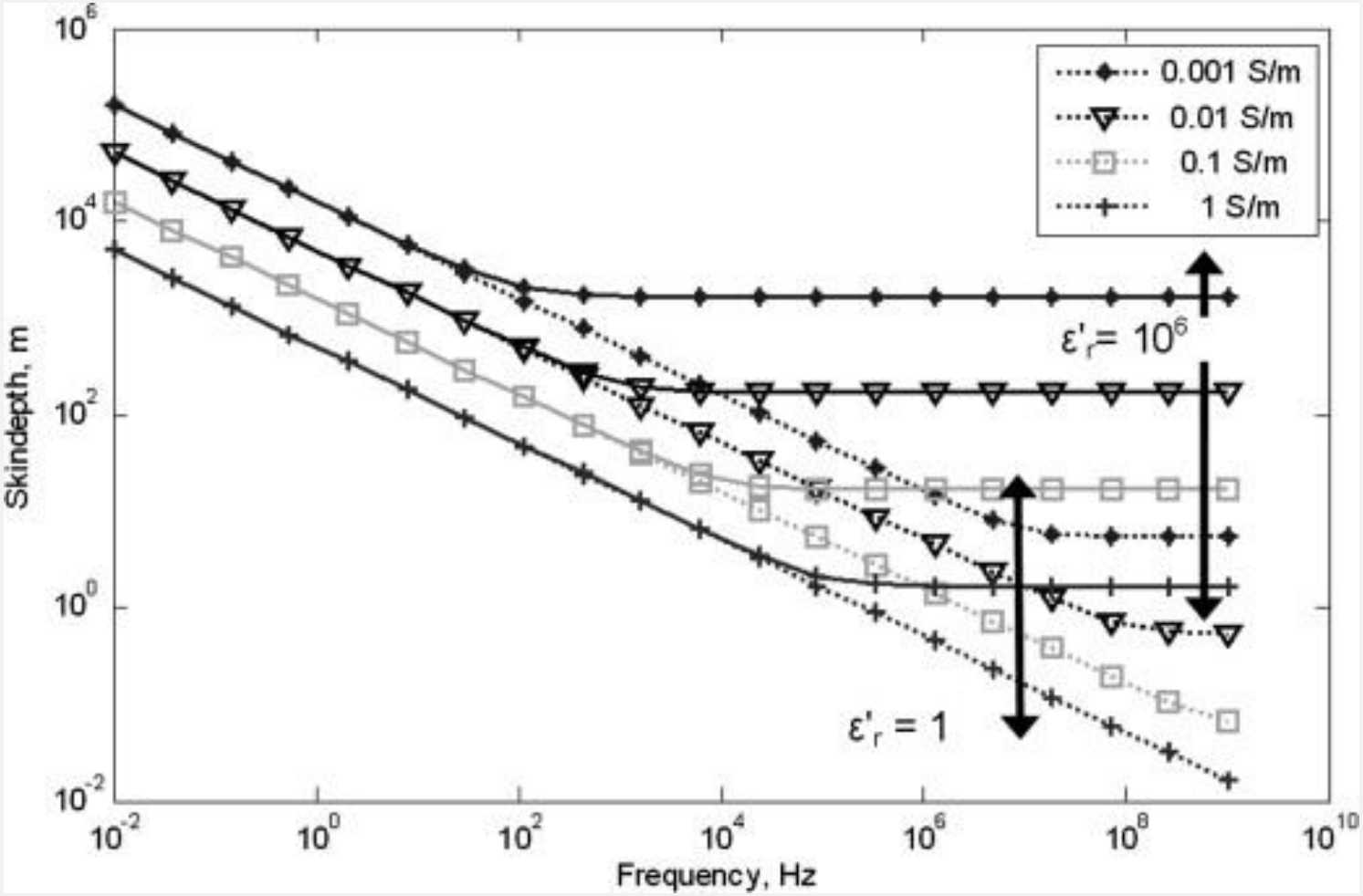
Four-wheel motorcycle holding the GPR system constituted of a horn antenna linked to a vector network analyzer, the DGPS device and the laptop.

Picture taken on the 23rd of March 2009 in a barley field near Walhain, Belgium

J. Minet et al. / Geoderma 161 (2011) 225–237

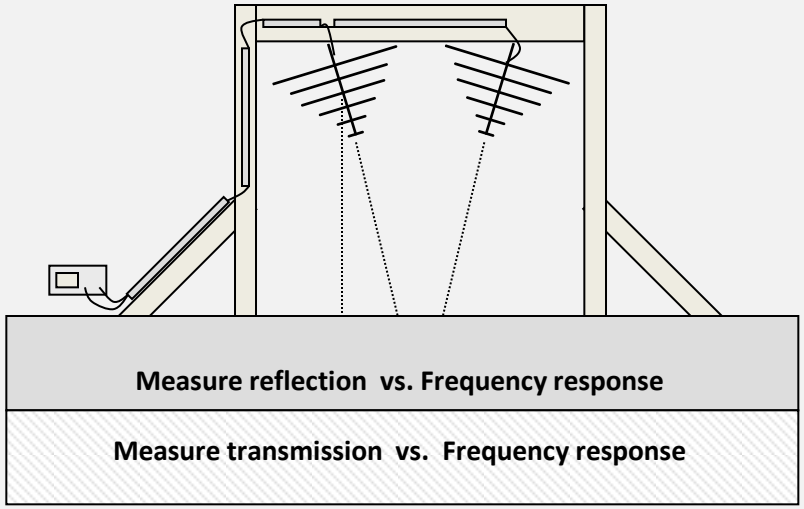
Ground penetrating RADAR

- Skin depth as a function of frequency



Metje, N., P.R. Atkins, M.J. Brennan, D.N. Chapman, H.M. Limb, J. Machell, J.M. Muggleton, S. Pennockf, J. Ratcliffe, M. Redfern, C.D.F. Rogers, A.J. Saul, Q. Shan, S. Swingler, A.M. Thomas. 2007. Mapping the Underworld – State-of-the-art review. Tunnelling and Underground Space Technology, 22(5–6): 568–586.

Precision Soil Sensing Research at OKState

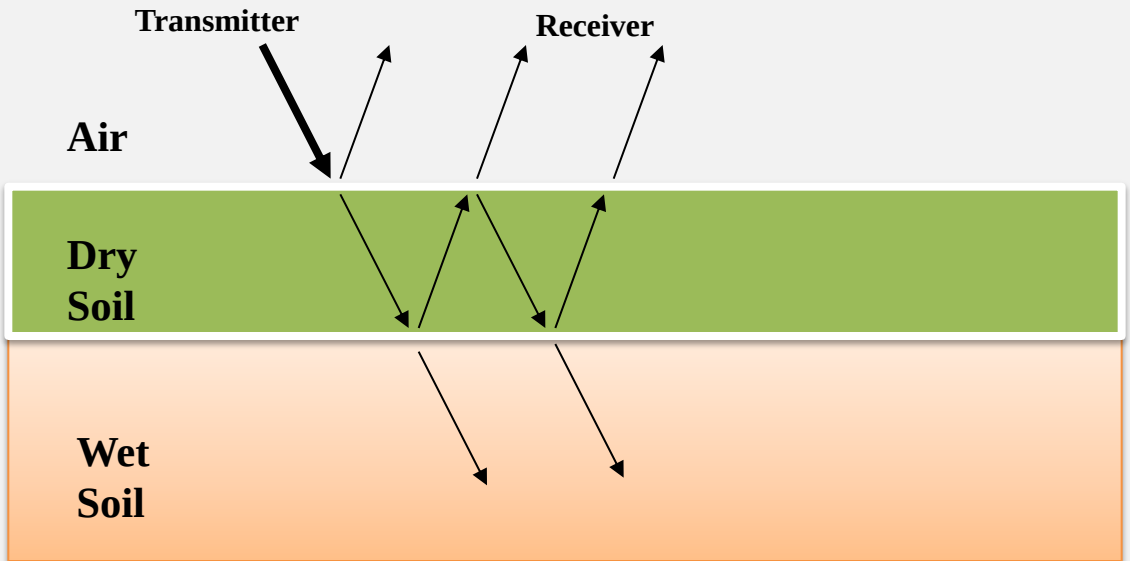


Radio Frequency Soil Moisture Sensing

Non-Contact Prediction of Soil Moisture Profiles using Radio Wave Reflection

Paper number 051034,
2005 ASAE Annual Meeting

Electromagnetic Reflection from Multiple Dielectric Slabs



SoilOptix® TECHNOLOGIES

Introducing the first system to generate high definition soil property maps using gamma-ray spectrometry

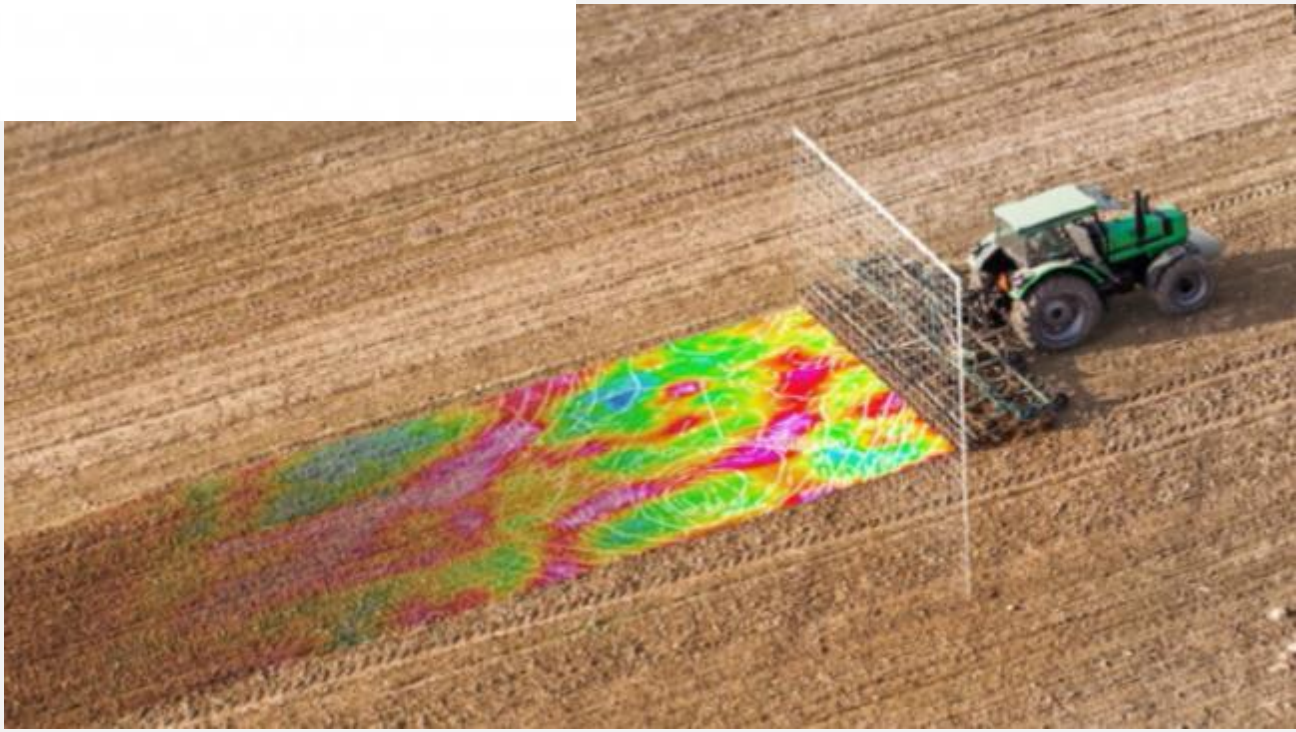
(Practical Precision Inc., Tavistock, ON, Canada).

Maps included are:

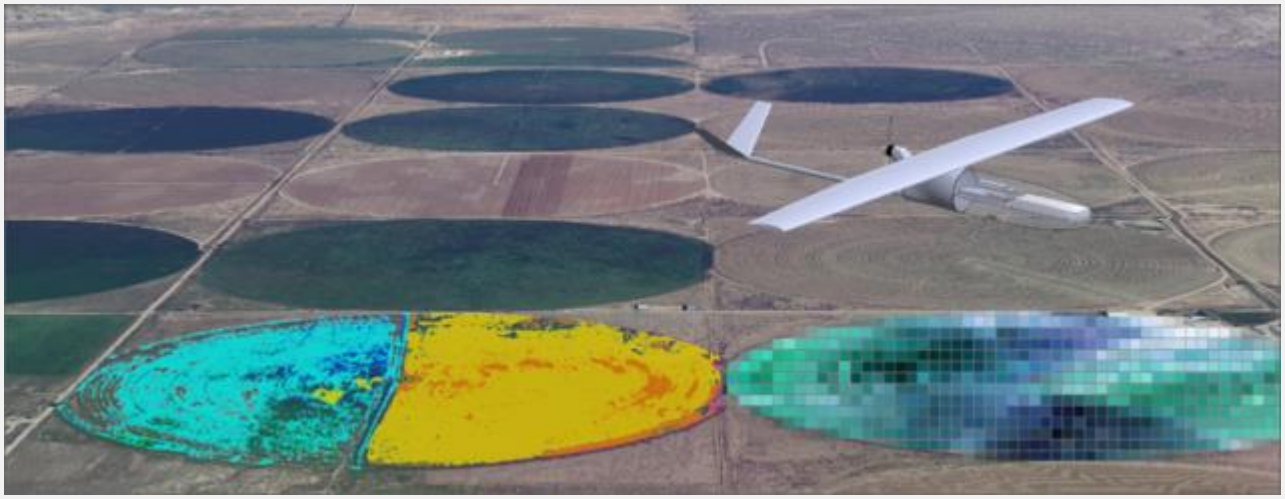
pH, Mg, P, OM, Ca, Base Saturation Mg, Base Saturation K, Base Saturation Ca, CEC, %Sand, %Silt, %Loam, K/Mg ratio, and Ca/Mg ratio.

GEOPROSPECTORS

Silver medal for innovation awarded to Geoprospectors at Agritechnica 2015 in Hanover

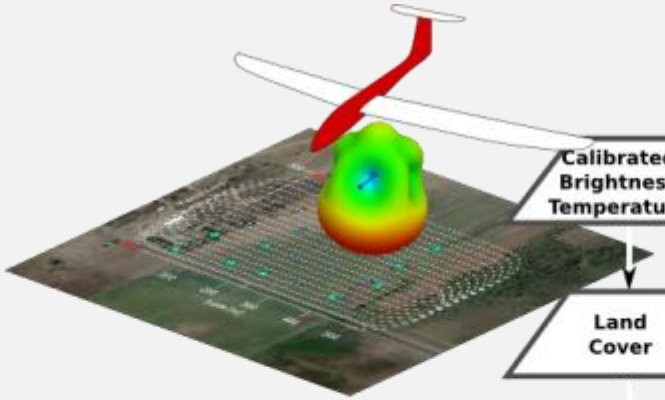


***Uses proven non-invasive geophysical measurement technologies**, such as electromagnetic induction, ground penetrating radar and gamma ray spectroscopy*



BlackSwift TECHNOLOGIES

We design and deploy specialized small Unmanned Aircraft Systems (sUAS) for user-specific, customized applications.



Calibrated Brightness Temperature

Land Cover

OK?

NO

YES

Soil Temperature

Computation of pixel emissivity

Vegetation Type and Water Content

Vegetation correction Jackson & Schmugge (91)

Vegetation correction Jackson & Schmugge (91)

Soil Roughness

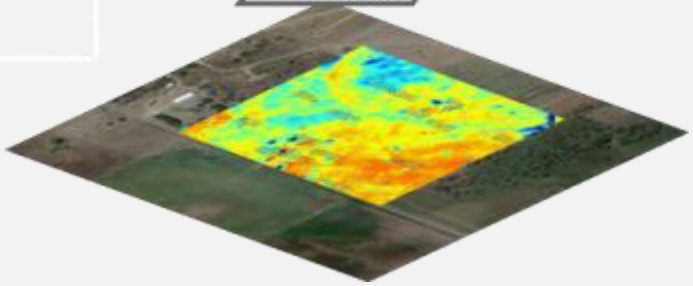
Roughness Correction Choudhury et al. (1978)

Inversion of Fresnel equations to obtain soil dielectric constant

Soil Texture

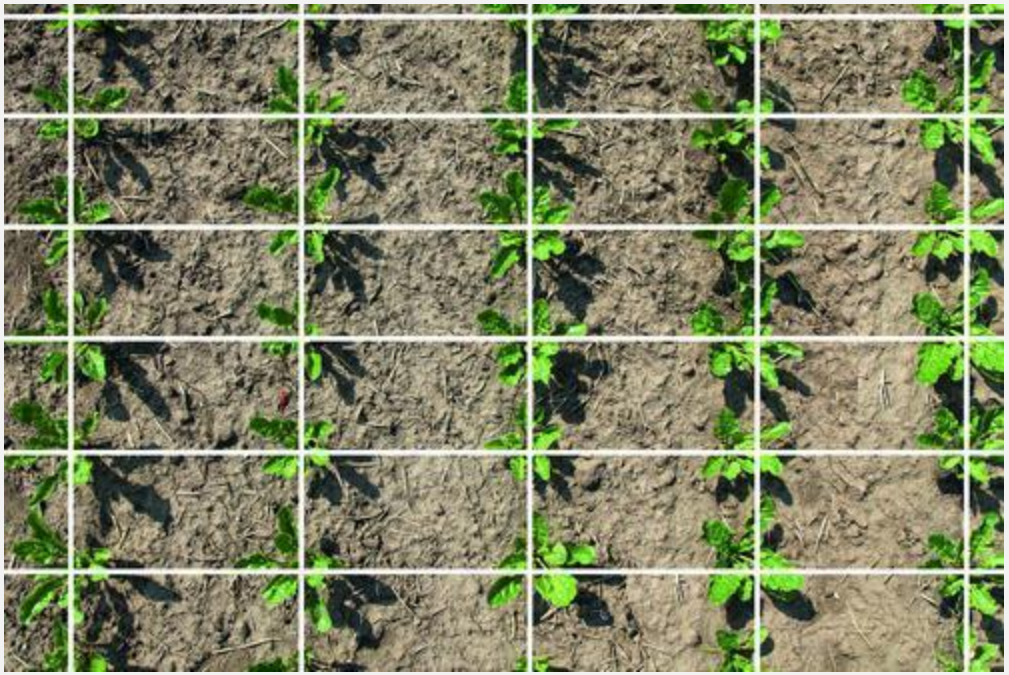
Computation of soil moisture Wang & Schmugge (1980)

Volumetric Soil Moisture



BlackSwift TECHNOLOGIES

Precision Planting

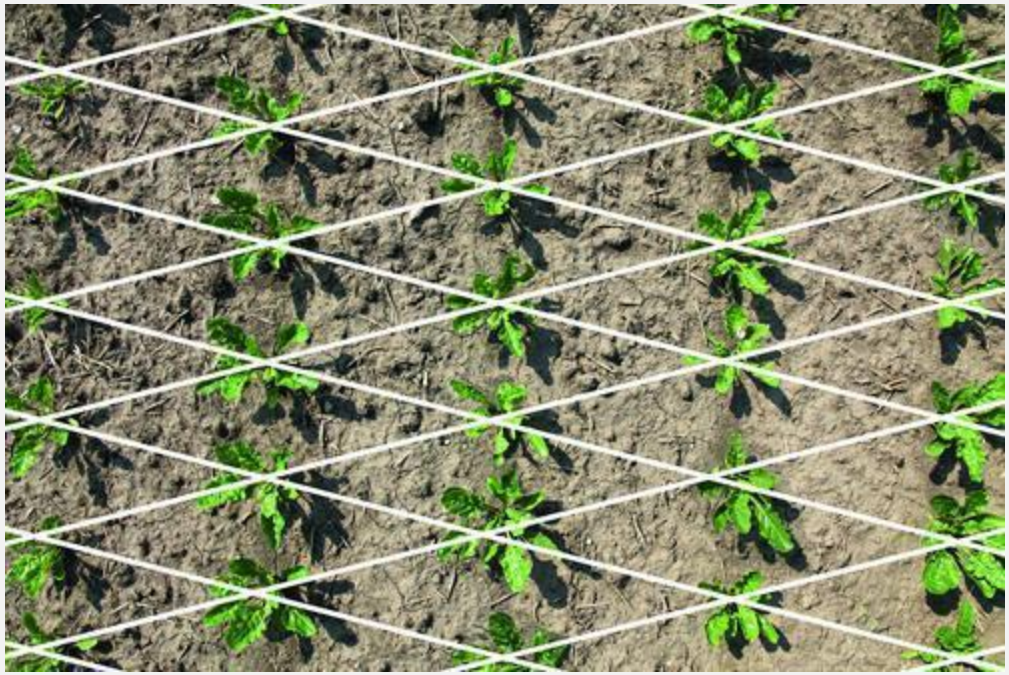


Kverneland

GEOseed® Level 2 is the synchronization in the whole field.

This is the necessary requirement for interrow cultivation, also across the seeding direction.

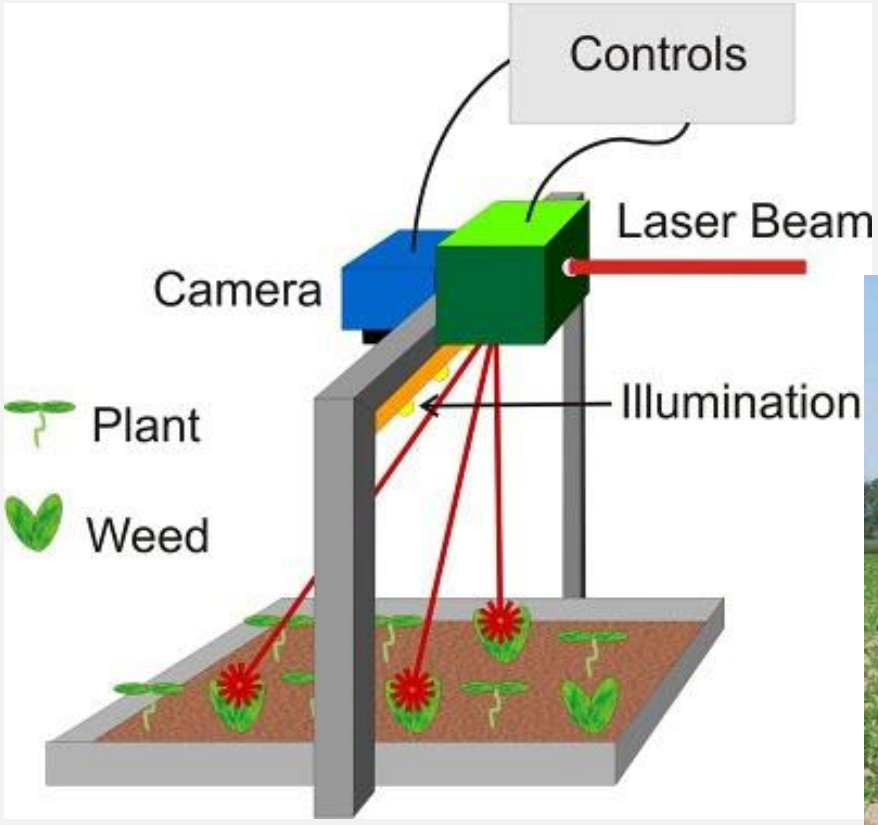
GEOseed® is the only system in the world, that makes this mechanic weeds control possible!



Mechanical Weeding

Christiaens
Agro Systems

Robot With Laser to Zap Weeds Automatically



Leibniz University Hannover /
Laser Zentrum Hannover eV

WAGENINGEN UR
For quality of life

Automatic lateral alignment of machine

Each hoeing tools individually controlled by separate Cameras

Hydraulic operated for long lifetime

On-board hydraulic and electric power supply

ROBOVATOR

Individual electronic adjustment of hoeing parameters
during operation

Hoeing tools are protected from overload by springs

Automated Agricultural Platform

It can be equipped with Vibro Crop Intelli sections for mechanical weed control or implements for precision seeding (Becker Aeromat or Centra), ridging discs and mechanical row crop cleaning units (Kongskilde Vibro Crop). -

FORTUNE

June 3, 2015

The startup behind the lettuce robot has a new 3D crop scanner

Blue River Technology — the startup that brought weed-killing lettuce robots to farms around California — quietly launched a 3D crop scanning tool last month

FORTUNE

The startup behind the lettuce robot has a new 3D crop scanner

Blue River Technology is starting out by selling its 3D crop scanning tool as a service to corn plant breeders ***(with a fee per acre)*** who are keenly interested in gathering information about crops grown from various seeds in field trials.

The company's initial corn breeder customers are mostly working in the midwest's corn belt…, but Blue River is also working with farms in California to gather data about trials for drought-tolerant crops.

Universities are interested in using it for crop genetic research as well.

The company is funded by Data Collective Venture Capital, Khosla Ventures, Eric Schmidt's Innovation Endeavors, Steve Blank, Ulu Ventures, and Stanford Angels.

The company closed on a $3.1 million seed round in 2012, and a $10 million round in 2014.

Started by a former executive with GPS company Trimble

MARWIS - a Mobile Advanced Road Weather Information Sensor

MARWIS delivers the following data: Road surface temperature, waterfilm height, dew point temperature; road conditions: dry, moist, wet, snow, ice; ice percentage; friction; rel. humidity, air temperature

Acknowledgements

Dr. Randy Taylor	Biosystems & Agricultural Engineering
Dr. Ning Wang	Biosystems & Agricultural Engineering
Dr. Marvin Stone	Biosystems & Agricultural Engineering
Dr. John Solie	Biosystems & Agricultural Engineering
Dr. Bill Raun	Plant & Soil Science
Dr. Brian Arnall	Plant & Soil Science
Dr. Tyson Ochsner	Plant & Soil Science
Dr. Chuck Bunting	Electrical & Computer Engineering
Dr. Jamey Jacob	Mechanical & Aerospace Engineering
Dr. Ken Sudduth	USDA-ARS, Columbia, MO
Dr. Bobby Grisso	Biological Systems Engineering, Virginia Tech
Dr. Slava Adamchuk	Bioresource Engineering, McGill Univ.

Low cost, accurate, high resolution, non-contact soil moisture sensors are needed

Questions or Comments?