



Food and Agriculture  
Organization of the  
United Nations

GLOSOLAN  
Soil spectroscopy  
training workshops

# Soil spectroscopy from the Danish perspective

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Online  
webinars





# OUTLINE

- FOSS
- The soil testing market
- The FOSS solution
- Summary and outlook

**FOSS**



# A HISTORY OF PIONEERING INVENTIONS

# FOSS



In 1956, Nils Foss identified the need for a portable moisture analyser

Fast, easy-to-use and dedicated, the Cera-Tester was the first FOSS innovation

Matching innovative technology to the demands of particular industries has been the foundation of FOSS ever since



1956

Cera Tester monitors moisture content in grain. The instrument is a highly popular world first.



1963

Milk becomes a major business area, and the Pro Milk helps to speed-up the analysis of fat content in milk.



1973

The Tecator Kjeltec™ paves the road for simpler, safer, less timeconsuming and more cost efficient Kjeldahl analysis.



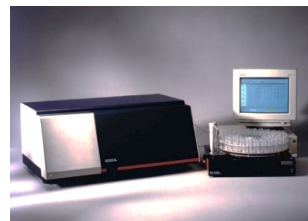
1980

Analysis of individual bacteria or somatic cells leads to dramatic improvements in raw milk quality.



1997

FOSS acquires Perstorp Analytical and improves consistency of analysis results throughout the grain industry via NIR.



1999

WineScan introduces FTIR analysis as an effective way of improving quality throughout the wine making process.



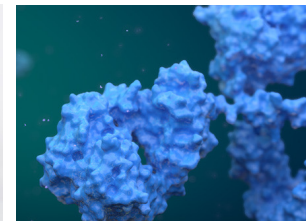
2003

Introduction of X-ray analysis of meat allows entire batches of meat to be checked for fat



2014

For the Indian market, FOSS introduces the tiny milk analyser, MilkoScreen™, for milk quality testing and adulteration screening



2016

FOSS acquires Soft Flow in Hungary, adding extensive knowledge within biotechnology



2020

The MilkoScan FT3 with new, patented automatic standardisation which eliminates the need to perform time consuming standardisation checks with chemical reagents.

## CORE TECHNOLOGIES

NIR

FT-IR

X-RAY

IMAGE ANALYSIS

FLOW CYTOMETRY

CHEMOMETRICS





# INDUSTRY LEADING SOLUTIONS FOR INDUSTRY LEADING CUSTOMERS

# FOSS

ANALYTICS BEYOND MEASURE

LABORATORIES



DAIRY



RAW MILK TESTING



WINE



MEAT



FEED & FORAGE



GRAIN & OILS



## KEY FIGURES

**100%**

A 100% family-owned company – HQ in Denmark

**99%**

99% of turnover outside Denmark

**288 mill.**

A turnover of 288 million EUR in 2020

**AAA**

AAA-rated by D&B

**> 24%**

EBITA of > 24% of turnover

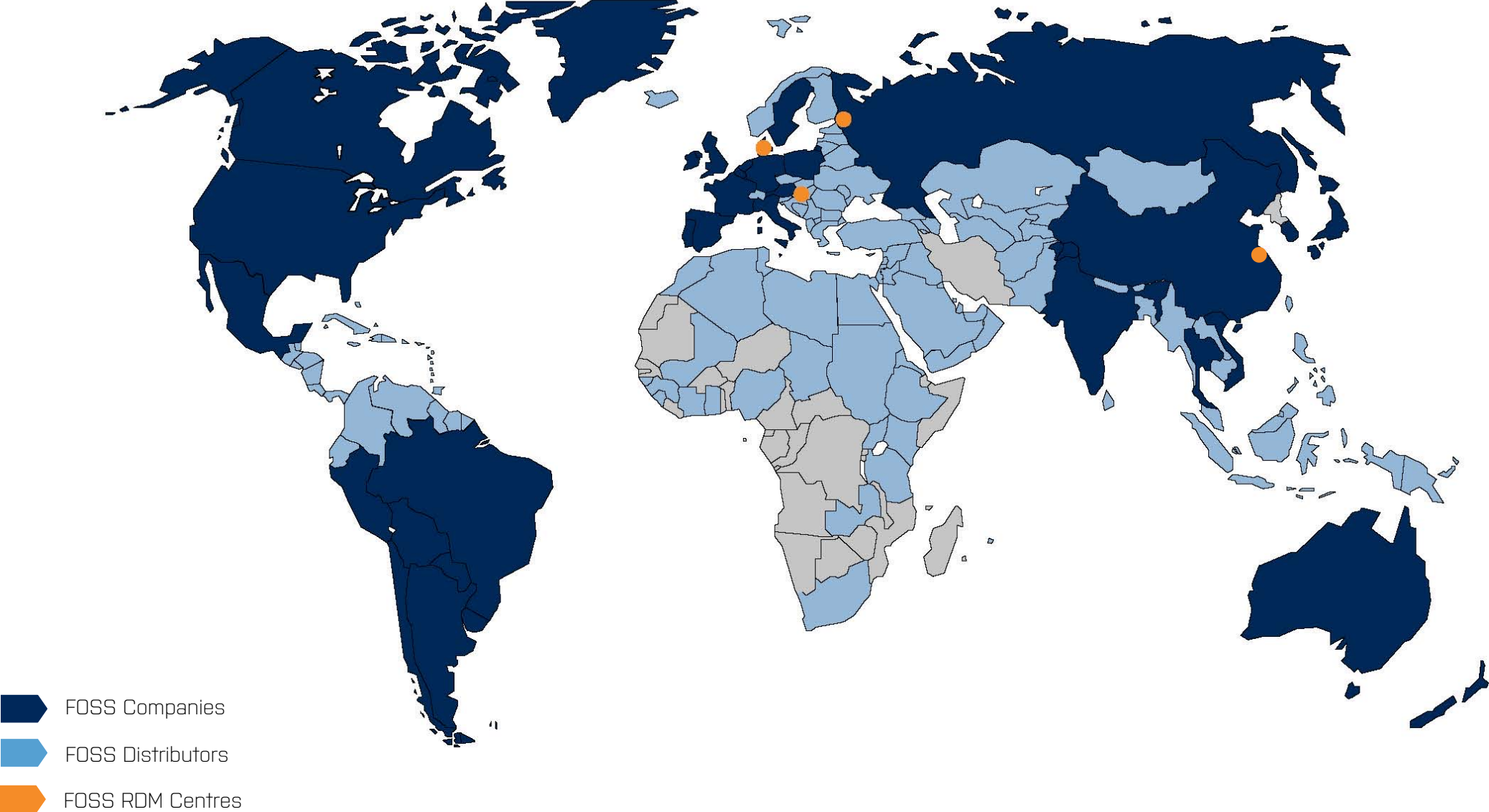
**> 54%**

Solvency ratio > 54%



# GLOBAL PRESENCE

# FOSS



ANALYTICS BEYOND MEASURE



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**FOSS**

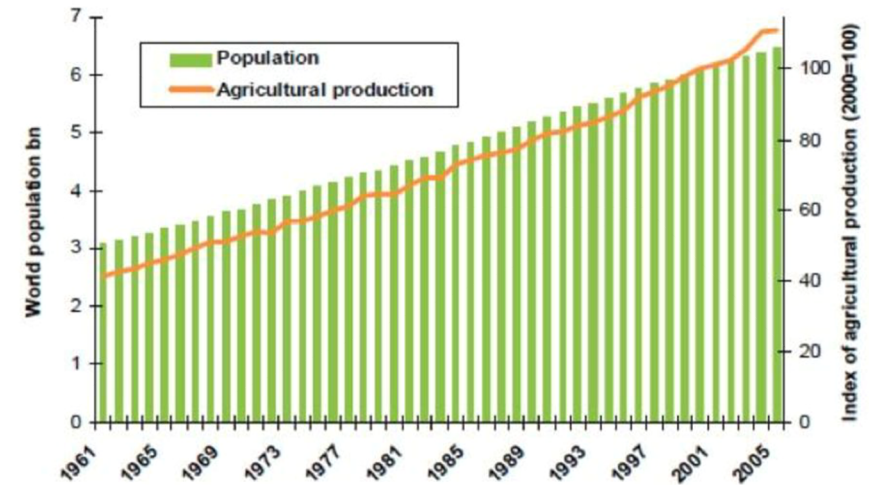




# MOTIVATION

- Feeding worlds population requires optimized farming and fertilization strategies
- Soil analysis is key!- “If you don’t measure it, you can’t manage it”
- Some soil analysis methods are slow, labor intensive and may require use of harsh chemicals
  - Most form 1<sup>st</sup> half of 20<sup>th</sup> century

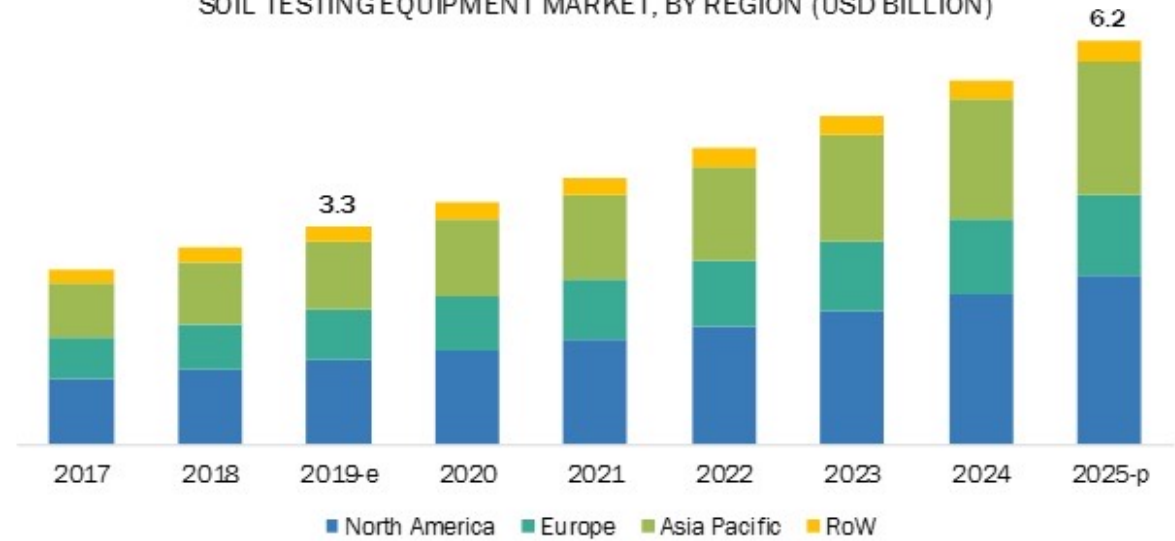
World population and agricultural production (2000=100) 1961-2005



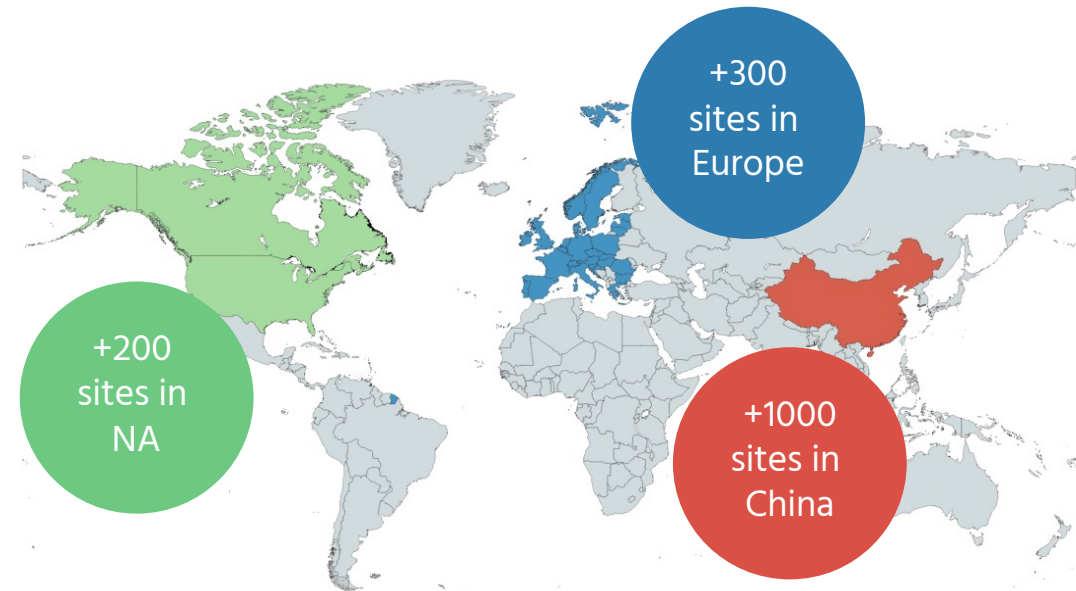
# MARKET DEVELOPMENT

- Development of soil testing follows general trends
- Annual growth ca. 10-15%
- Consolidation of labs
- Driven by
  - Soil management
  - Legislation
  - Megatrends

SOIL TESTING EQUIPMENT MARKET, BY REGION (USD BILLION)



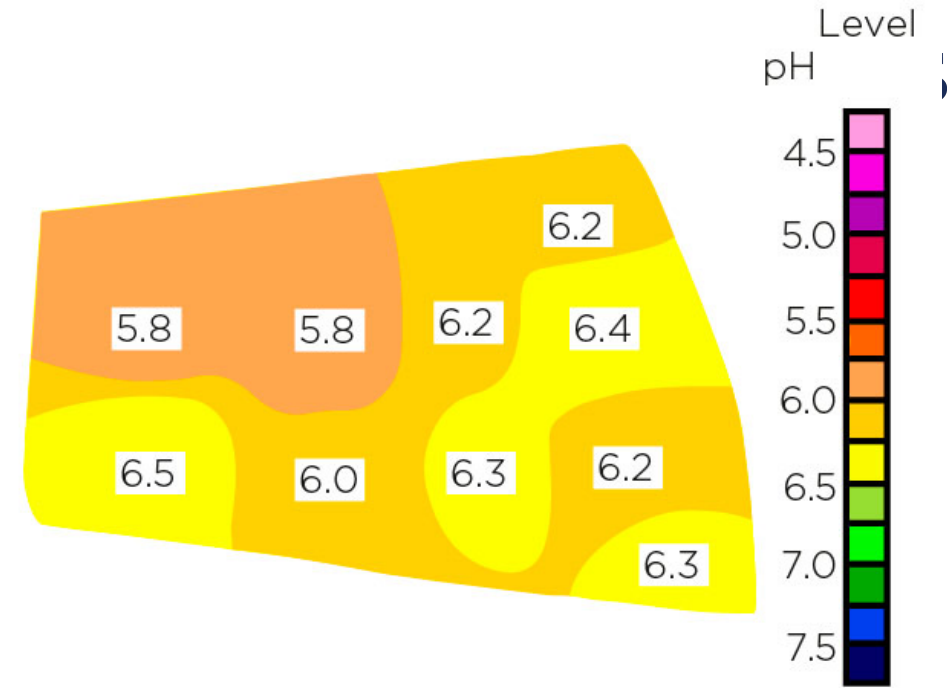
Soil testing laboratories





# MEGATREND: PRECISION FARMING

- Soil is diverse, but traditional analysis are expensive
- Reduced analysis and reduced productivity
- Low cost sensors and measurements for increased insight and yield



ANALYTICS BEYOND MEASURE



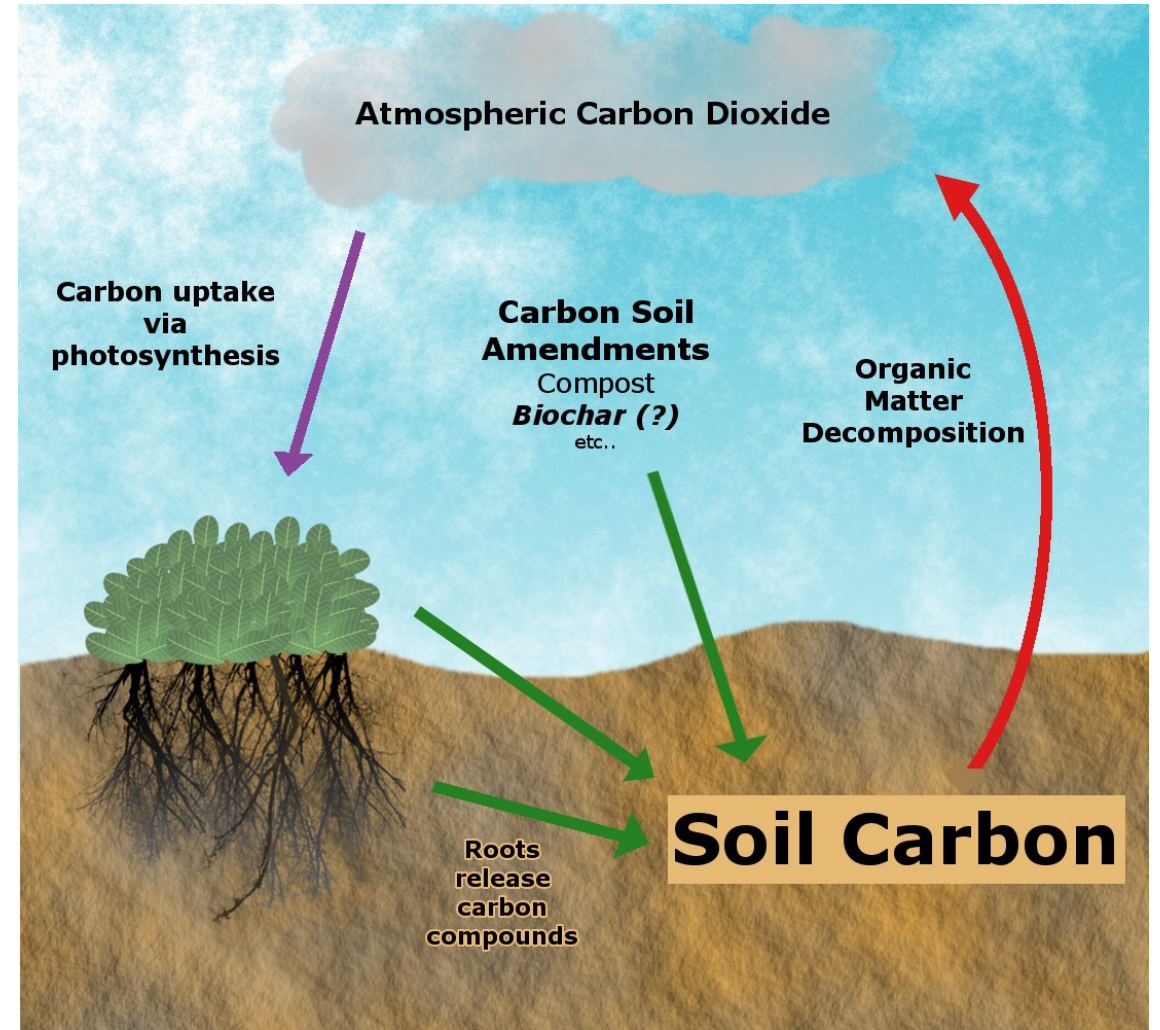
JOHN DEERE



# MEGATREND: CO2 SEQUESTRATION IN SOIL

# FOSS

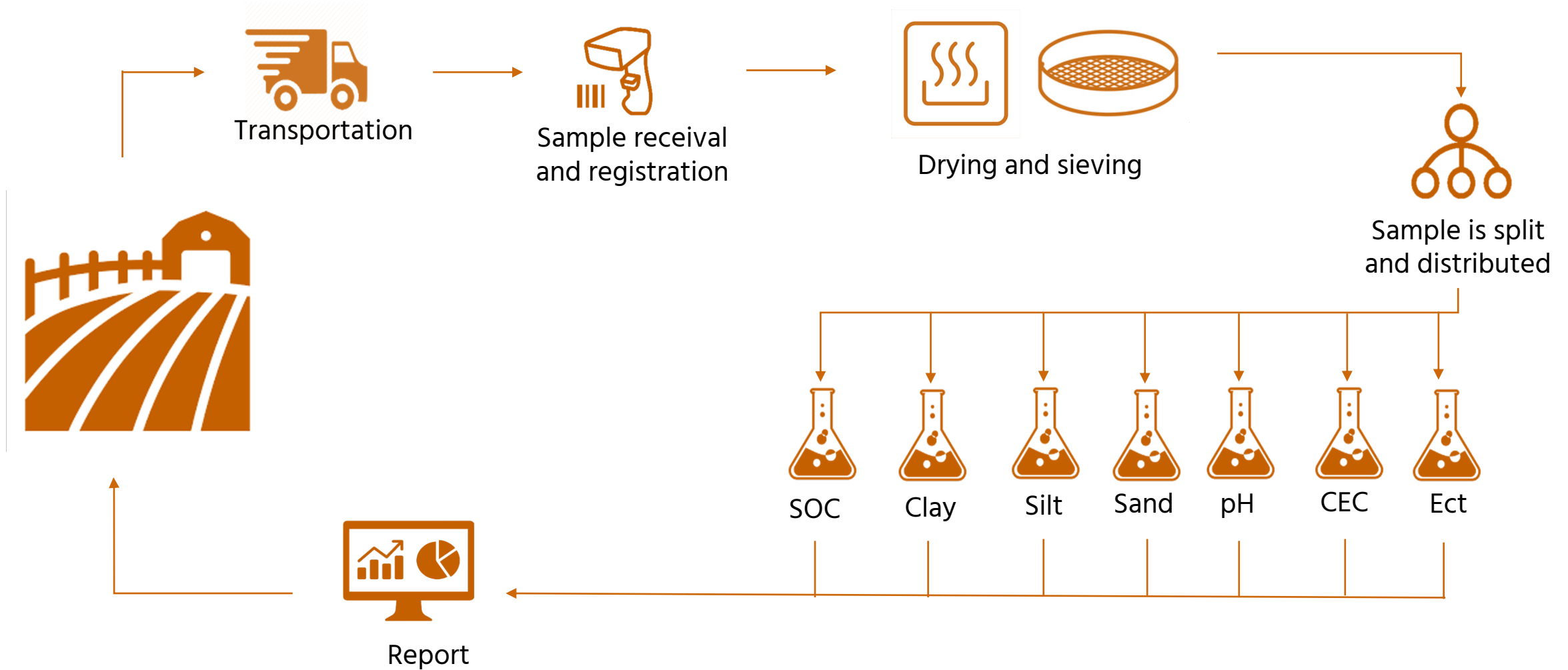
- Healthy soil contains carbon (SOC)
- SOC levels are known to have decreased
- CO<sub>2</sub> sequestration by improved land use
- Seen as a win-win initiative
- Substantial rollout of platforms and investments



ANALYTICS BEYOND MEASURE



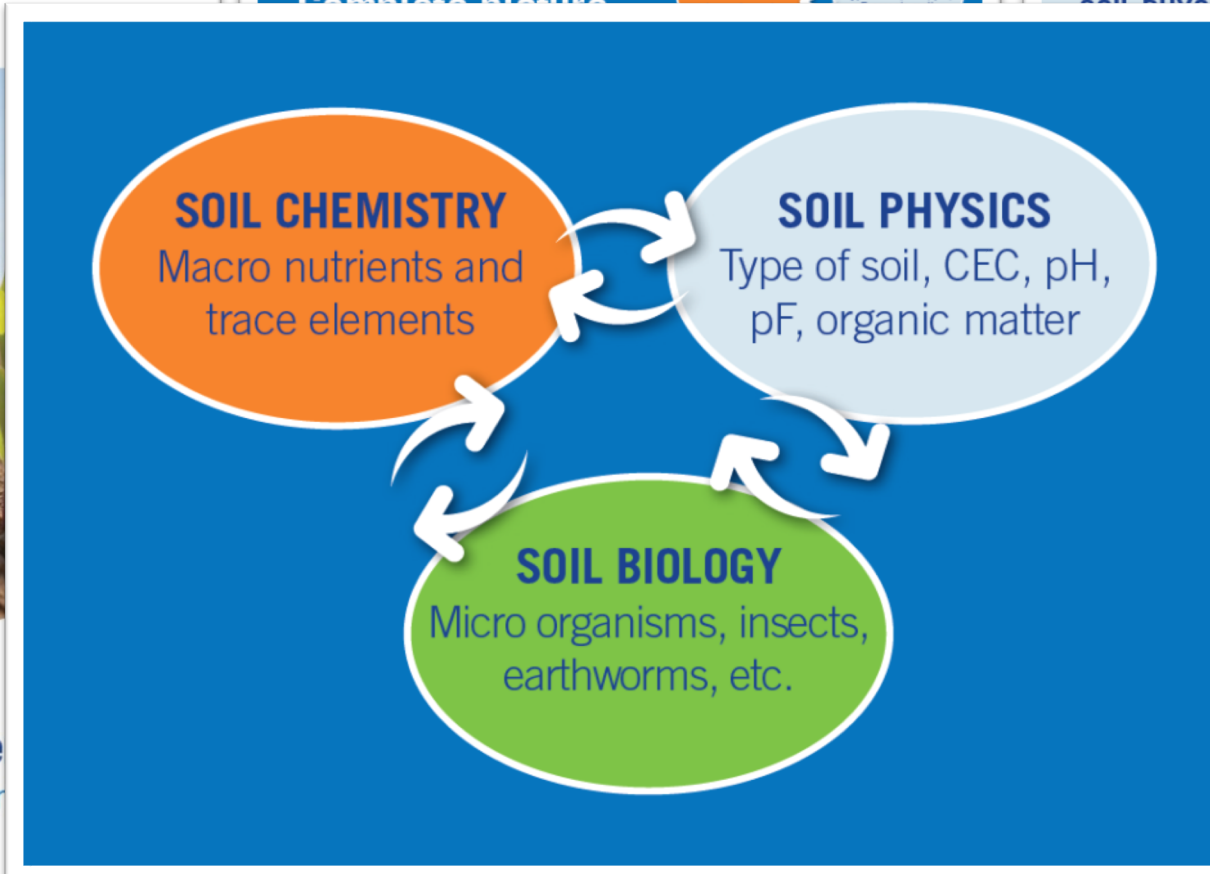
# SAMPLE WORKFLOW - FROM THE CUSTOMERS SITE TO THE LAB





**Fertilization Manager**  
Basis for smart fertilization

growing insight



**SOIL PHYSICS**

The physical properties of the soil create the conditions for plant growth and development. They also determine how the chemical and biological processes in the soil operate. Fertilization Manager reports the physical properties of the soil like among others clay, silt, sand, pH, CaCO<sub>3</sub>, soil organic matter and soil organic carbon.

**Quality and content of organic matter**

Organic matter are presented in key... of organic matter in the soil... moisture retention capacity of... for soil organisms.

Organic matter consists mainly of carbon (C), nitrogen (N), sulphur (S) and phosphorus (P). The ratios of these elements determine the quality of the organic matter. Stable organic matter contains high levels of C and improves the soil structure, moisture retention capacity and CEC binding. Dynamic organic matter contains high levels of N and S and breaks down easily (mineralization).

**Soil type and moisture retention capacity**

The size and distribution of particles determine the type of soil. Fertilization Manager distinguishes between clay, silt and sand. Both the percentages and a texture triangle are provided.

Fertilization Manager also presents a pF-curve. This curve provides information on the maximum amount of water the soil can hold (field capacity), the point at which the soil retains so little water that the uptake by the plant roots is limited (wilting point) and the point at which the moisture in the soil would need to be topped up to prevent problems (maximum soil water deficit). The pF-curve is a useful tool for calculating the maximum quantity of irrigation needed.

**Soil structure and CEC**

Clay and humus particles have a negative charge, so they attract positively charged nutrients, the cations, such as potassium (K), magnesium (Mg), calcium (Ca), ammonium (NH<sub>4</sub>) and sodium (Na). The composition of the clay-humus complex is an indicator of possible problems with soil structure.

Fertilization Manager reports the CEC of the soil, both as a percentage and in a structure triangle. CEC stands for Cation Exchange Capacity. The CEC indicates how many nutrients are bound to the clay-humus complex. The main cations on the CEC are Ca, Mg, K and Na. Additionally, aluminium (Al), iron (Fe), manganese (Mn) and hydrogen (H) may also be present.

**WILTING POINT**

**IRRIGATION POINT**

**FIELD CAPACITY**

30 40 50

time (%)

**Mg-CEC (%)**

**Fe-CEC (%)**

■ optimal structure ■ moderate structure ● your plot  
■ good structure ■ bad structure  
■ reasonable structure ■ poor structure





# PARAMETERS

- Very many parameters can be analyzed
  - Site dependent
  - Season dependent
  - Crop dependent
- Spectroscopy can tackle few, but central parameters

Parameter	Accuracy range (RMSEP)**
SOC (%)	0.35 to 0.40%
Clay (%)	2.6 to 7.4%
Silt* (%)	2.5 to 6.5%
Sand* (%)	4.3 to 11.5%
pH*	0.4 to 0.5
CEC* (cmol(+)/kg)	2.5 to 2.7

## Pakete Bodenuntersuchung NIRS

Parameter	Methode	Basis	Basis Plus	Profi	Premium - Düngekompass	Bodenart	Kationenaustauschkapazität (KAK)
N-Vorrat	NIRS	x	x	x	x		
C/N-Verhältnis	berechnet	x	x	x	x		
N-Nachlieferung	NIRS	x	x	x	x		
S-verfügbar	CaCl2				x		
S-Vorrat	NIRS		x	x	x		
C/S-Verhältnis	berechnet		x	x	x		
S-Nachlieferung	NIRS		x	x	x		
P-verfügbar	CaCl2		x	x	x		
P-Vorrat	NIRS	x	x	x	x		
K-verfügbar	CaCl2				x		
K-Vorrat	NIRS	x	x	x	x		
Ca-verfügbar	CaCl2		x	x	x		
Ca-Vorrat	NIRS		x	x	x		x
Mg-verfügbar	CaCl2				x		
Mg-Vorrat	NIRS	x	x	x	x		
Na-verfügbar	CaCl2				x		
Na-Vorrat	NIRS				x		x
Säuregrad (pH)	NIRS	x	x	x	x		x
C-organisch	NIRS	x	x	x	x		
Organische Substanz	NIRS	x	x	x	x	x	
C/OS-Verhältnis	berechnet		x	x	x		
Kohlensäurer Kalk	NIRS	x	x	x	x	x	
Ton	NIRS	x	x	x	x	x	
Schluff	NIRS	x	x	x	x	x	
Sand	NIRS	x	x	x	x	x	
<16 µm	NIRS	x	x	x	x	x	
Ton-Humus (KAK)	NIRS			x	x		
CEC-Besatz	NIRS			x	x		x
Ca-Besatz	NIRS			x	x		x
Mg-Besatz	NIRS			x	x		x
K-Besatz	NIRS			x	x		x
Na-Besatz	NIRS			x	x		x
H-Besatz	NIRS			x	x		x
Al-Besatz	NIRS			x	x		x
Krümelbarkeit	berechnet		x	x	x		
Verschlämmungsrisiko	berechnet		x	x	x		
Erosionsempfindlichkeit	berechnet		x	x	x		
Wasserhaltevermögen	berechnet		x	x	x		
Microbial biomass	NIRS				x		
Mikrobielle Aktivität	NIRS	x	x	x	x		
Pilze/Bakterien-Ratio	NIRS				x		
Düngerempfehlung	berechnet	soil based	soil based	soil based	crop and soil based		
Organische Substanzbilanz	berechnet	x	x	x	x		
Strukturdreieck	berechnet			x	x		x
Texturdreiecks	berechnet	x	x	x	x		
pF-Kurve	berechnet		x	x	x		
P-Pufferkapazität	berechnet				x		
EC	NIRS	o	o	x	x	o	o
Spurenelemente: Si, Fe, Zn, Mn, Cu, Co, B, Mo, Se	CaCl2	o	o	o	o	o	o

x: im Paket enthalten  
o: optional zubuchbar

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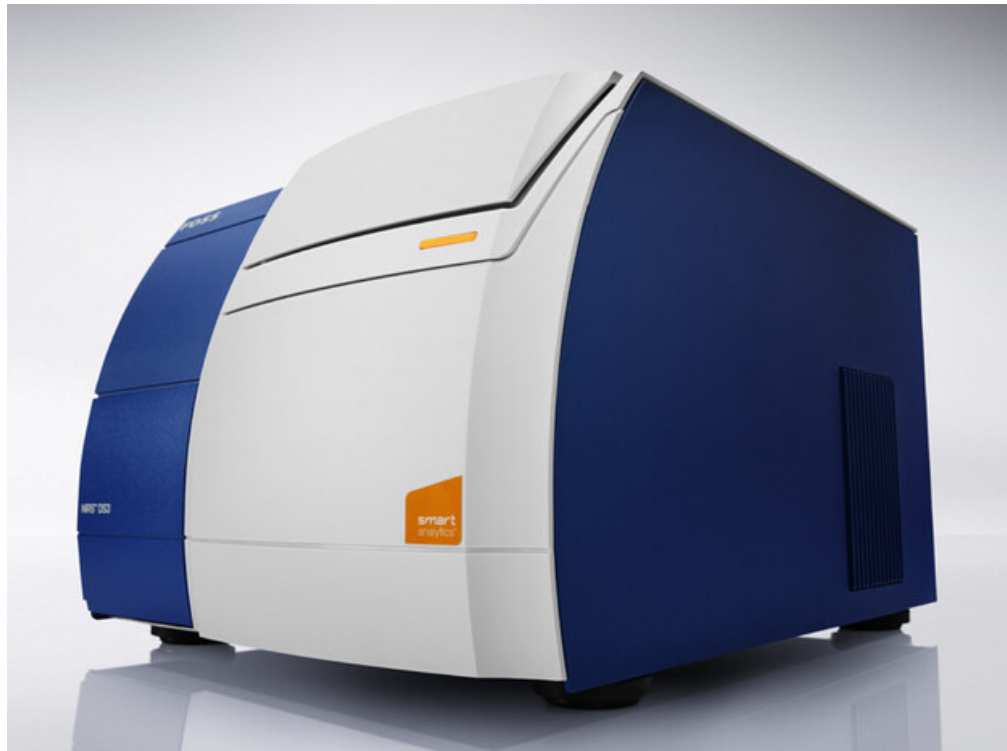




# BENCH NIR SOLUTIONS FROM FOSS

DS3

**FOSS**








## Main benefits

- Top performing NIR analyzer
- Wavelength range of 400 - 2500 nm
- Fully standardized: Identical performance across instruments
- IP 65
- Fast and easy to use
- Digital services and calibration options

# SOIL APPLICATION PACKAGE

# FOSS

 <b>DS3</b>	 <b>Digital Services</b>	 <b>Digital Training</b>	 <b>Application Guide</b>	 <b>Starter Data Pack</b>
<p>FOSS NIR instrument and accessories : DS3, sample cups etc.</p>	<p>Data management, calibration development, maintenance and distribution</p>	<p>Training (eLearning) courses in use of instruments and FOSS' digital solutions for customers and SSS'</p>	<p>Application guide covering expected performance and step by step guide for sample handling and calibration development using Foss Digital Services</p>	<p>Starter data package with FOSS owned reference and scans data for soil analysis</p>



# EXAMPLE FROM PROJECT WITH MAJOR SOIL LAB

- “NIR error” comparable to “REF error” (RMSEP)
- Outliers are apparent ... but where is the error
  - Re-analysis showed that in **all of the cases** the reference value was incorrect
- Sources of error:
  - Weighing
  - Manual data transfer
  - Down-sampling

Parameters	NIR error	REF error
SOC (%)	0.38	0.31

Origin of error	NIR	REF
Method	Yellow	Green
Sample preparation	Green	Yellow
Sampling	Red	Red

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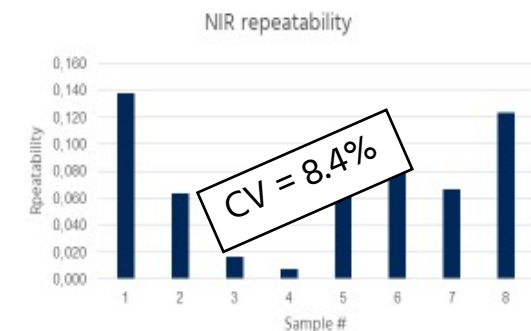
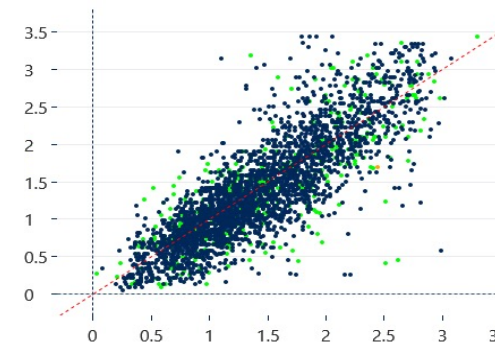




# CONCLUSIONS

# FOSS

- NIR for soil:
  - Fast, and easy to use, and cost effective
  - Minimal sample preparation
  - Easy database management and calibration development via dedicated SW
  - 100% of investigated outliers due lab error
  - Better repeatability than reference
- **NIR is a very suitable technology for handling large amounts of soil samples with high variance**



THANK YOU













Soil is very complex matrix. Global models are not yet available.

Massive amounts of local data is readily available for reference laboratory.

DIY application development has been made accessible for end user

**Contact FOSS local representative!**

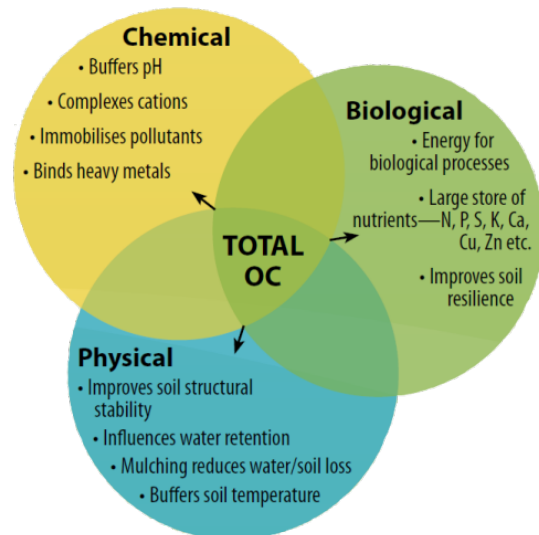
Content	Appl. Guide	Appl. Note
Description of application		
Description of instrument		
Description of sample prep.		
Description of sample presentation		

# REFERENCE METHODS – SOIL ORGANIC CARBON

# FOSS

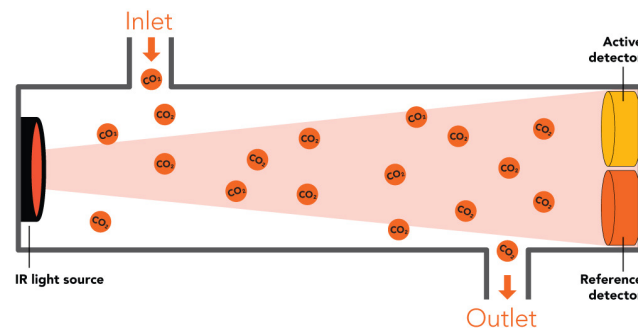
Descriptive of overall soil health

Relevant for CO<sub>2</sub> sequestration



## Method 1: Elemental analysis

- Gasify and analyse by NDIR
  - $\text{SOC} + \text{heat} \rightarrow \text{CO}_2$
- Pro: Automated, hands-off
- Con: Expensive apparatus, downsample



## Method 2: Walkley Black

- Oxidize C by chromic acid and colorimetry/titration
  - $\text{SOC} + \text{Cr(VI)} \rightarrow \text{Cr(III)}$
- Pro: Simple equipment
- Con: Hazardous chemicals, downsample





# REFERENCE METHODS - TEXTURE

- Particle size distribution
  - Water and nutrient holding, aeration, tillage
- Gravimetry/sedimentation
- Pro: Simple and cheap
- Con: Labour intensive, slow, need for chemicals, footprint

